THE DIORITES AND GRANITES OF SWIFT'S CREEK AND THEIR CONTACT ZONES, WITH NOTES ON THE AURIFEROUS DEPOSITS.

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By A. W. Howitt, F.G.S.

[Read 12th June, 1879.]

Introduction, and Description of the Physical Features of the District.

It is now nearly fifteen years since my attention was first directed to the peculiar physical and geological features of the Swift's Creek District, near Omeo. During that long period I have from time to time made observations as to the rock masses found there, but it was not until five years back that I seriously set myself to the task of systematically collecting data, and of endeavouring to trace out and explain therefrom their geological history, while describing and classifying the various formations occurring at that place. Before recording the results of these observations on the geology of Swift's Creek, it may be as well to describe shortly the physical geography of the part of Victoria in which that place is situated.

If we take a general view of Eastern Victoria, we shall perceive that it consists of a vast extent of mountains, known as the Australian Alps, which are flanked to the south by lower lying tracts, stretching from the foothills to the sea, and to the north by the extensive levels of the Murray basin. The central mountain mass may be further described as being formed mainly of highly-inclined Lower palœozoic strata, on the denuded edges of which rest isolated tracts, either of upper palœozoic formations, or of Tertiary volcanic streets.

The mountainous area rises to heights of nearly 7000 feet above the sea level, and snow accumulates upon them for many months of the year. The formations of Tertiary age which fringe the mountains on each side rise on their flanks to elevations which do not, according to my measurements, exceed 800 feet above sea-level, and often fall short of that height. If we, therefore, picture to ourselves a contour line extending from the south-eastern boundary line of this colony, near Cape Howe, westward through Gippsland, at an elevation of from 700 to 800 feet, it would define approximately the upper limit of the marine tertiaries; or, in other words, the maximum level in respect to the mountain mass at which the sea has stood during Cainozoic time, or still more properly, it would represent the total elevation of the land above sea-level during that period. But in the latter case it would be necessary to add to that elevation of 700 or 800 feet also the depth at which the continuation of the older leads would, if traced out, emerge below the level of the sea. An extension of such a contour line round the northern slopes of the mountains would also define similar features in the Murray basin, where, however, the conditions were probably lacustrine. It is of interest to observe that this same contour line would also approximately mark a zone within which the flora—as, for instance, species of eucalyptus—differ from those met with at higher levels. From this upper margin of the marine tertiaries rise the first tiers of mountains composed of palœozoic rocks. Higher again than these commence the elevated plateaux—such as Omeo and Gelantipy, in which the rocks are mainly palœozoic, but are also in places Tertiary volcanic. The vegetation of these plateaux approaches an alpine character; the country is generally open and well grassed, and, again, marked by peculiar species of eucalypti. The grassy character of the country becomes still more predominant in ascending to greater elevations, until at about 5000 feet above sea-level the eucalyptus forests cease, and the highest plateaux and mountain summits are thickly clothed with snow-grass and alpine plants.

These mountain plateaux are a peculiar feature of the Australian Alps. An extended examination has shown me that they are the remains of a once vast tableland which stretched from Victoria far round the eastern coast of Australia, and the width of which in this colony may be roughly defined by Mount Wellington in the south and Mount Buffalo in the north. Leaving out of consideration smaller tracts—such as the summit of Mount Useful—it is evident that the high plains of Wonnangatta, the Dargo, and the Bogong, the tablelands of Omeo, Nunnyong, and Gelantipy, are connected by similar physical features, elevation, climate, and vegetation with the extensive plateau of Maneroo. These remarks, when somewhat modified, are equally applicable to the northern slopes of the mountains and to the low-lying, probably lacustrine, deposits of the Upper Murray basin.

The district of Swift's Creek lies immediately south of the Great Dividing Range, which alone separates it from Omeo, and it may be classed with the upper part of the second and the lower part of the third zone. Swift's Creek takes its rise on a small plateau, which is scarcely more than a ledge, attached to the Omeo tableland, and falls rapidly through deeply eroded valleys to the Tambo River. This plateau is locally known as the Gum Forest. It is thickly grassed, and lightly timbered with white gum; while in the lower part of the stream the valleys are steep, with high-pointed ridges, and clothed with grass and an open forest of white box and apple-tree. Thus we have here those features well defined in miniature which I have indicated as general to the whole of the North Gippsland Mountains.

The examinations made by Mr. Reginald Murray and myself, of which the results have been published in the *Reports of Progress of the Geological Survey of Victoria*, show that during Miocene times the vast tableland which I have indicated still existed. Terrestrial conditions which have been continuous until now have sculptured the surface of that plateau as we now find it—a land of deep valleys and corresponding mountains. The volcanic portions of these highlands have been deeply excavated and lessened in extent, and during that vast period the surrounding higher points have been reduced in altitude. Thus the tableland has become separated into isolated parts of greater or less extent, and for long distances so entirely removed that a simple ridge is all that remains now, forming the Great Dividing Range.

It is evident that during these terrestrial conditions our existing alluvial gold workings of Gippsland were mainly accumulated, and that while some alluviums of age contemporaneous with or earlier than the Miocene period were sealed up in their valleys by flows of basalt, other auriferous deposits of such age suffered continuous rearrangement up to recent times as the streams gradually deepened their valleys with greater or less rapidity in accordance with the varying oscillations of the land.

The gold-bearing quartz veins in the Silurian formations, in the metamorphic schists, and, as I shall show, in the metamorphosed rocks in contact with intrusive quartz diorites and granites, contributed to these deposits.* Some Upper palœozoic conglomerates which have been derived from those older formations also contributed, and other sources may have existed in the abraded and worn rock masses, which we cannot now point out.

Definitions of the Terms Used in this Essay to Describe the Igneous Rocks.

Felsite is a compact or micro-crystalline granular compound of orthoclase-felspar and quartz. When it contains orthoclase crystals it is *porphyritic felsite* (felspar porphyry); when it contains quartz crystals it is a *quartz felsite* (quartz porphyry); when the felspar is not orthoclase, but plagioclase, the rock is a *plagioclase felsite.*

Granitite is composed of quartz, orthoclase, plagioclase, and magnesia mica.†

Amphibole granite is composed of quartz, orthoclase, plagioclase, and hornblende.†

Diorite is composed of plagioclase and hornblende; plagioclase and magnesia mica constitute *mica-diorite.* The addition of quartz to either of the above forms a *quartz-diorite* or a *quartz mica diorite.*

Amphibolite is a rock composed essentially of more or less perfect crystals of amphibole confusedly aggregated together.

Diabase is a granular compound essentially of plagioclase and augite, to which are associated chlorite and magnetite. The term is applied to the pretertiary representatives of dolerite.

To the above is added the contact rock *aplite* or *semi-granite,* which is a granular compound of potash felspar (orthoclase or microcline) and quartz, with muscovite mica as an accessory, and, in very rare cases, plagioclase.

Note.—The crystallo-graphic notation made use of is that of Professor J. D. Dana.

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* In the New London Reef, Happy Valley, near Myrtleford, I found that the auriferous rock worked was, in fact, a very quartzose variety of hornfels. The auriferous portion could not be called a true vein, but resembled more some of the contemporaneous segregations of quartz found in the crystalline schists.

† *Rosenbusch Mikroskopische Physiographie der Massigen Gesteine,* p. 19.

PART I.

1. General Geology of the District.

In making an extended geological examination of North Gippsland—the oldest formation anywhere met with is a recurrent series of greatly inclined and slightly metamorphosed slates and sandstone, with quartz veins. These rocks vary from an almost purely argillaceous to an almost purely arenaceous composition. Slaty cleavage is always more or less present. That the strata have been greatly denuded before Upper palœozoic times, is evidenced by their extreme unconformity with these Devonian sediments, which in various localities still rest upon them. In Gippsland, as in various other parts of Victoria, it is found that the older palœozoic sediments, after being tilted, compressed, and more or less metamorphosed, have been extensively intruded into by vast granitic masses, which, on an examination of the contacts, are not found to have generally disturbed the strike of the slates as prevailing in the district, except immediately at the contact, where they have truncated, crumpled, turned back and broken up the beds. This is more especially the case when the contact crosses the strike of the sediments. In the direction of the dip the strata usually incline both against and from the granite masses; and it is also seen that, especially when the sedimentary rocks have been cut across, granitic apophyses and veins penetrate the strata, and that portions of the latter are occasionally found included in the granite, and either completely cut off from the main mass, or merely attached to it by irregular portions of strata.

This vast recurrent series of palœozoic sediments, together with the intrusive granitic masses, is in Gippsland found to be older than the Middle Devonian marine limestones, which, as at near Buchan and Bindi, rest upon the denuded surface of both. In other localities, however, younger sediments have evidently been involved in the general folding. These younger sediments are distinguished from the Lower silurian formation, not only by fossiliferous beds fixing their age* as Upper silurian and Middle Devonian, but also by the peculiar

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* *The Devonian Rocks of North Gippsland*, by A. W. Howitt. *Report of Progress of Geological Survey of Victoria*, Part III., p. 183, *et infra.*

lithological character of the sediments themselves. Such cases occur at the Limestone River, and at Tabberabbera. From this we are justified in concluding that the folding, compression, and denudation of the older palœozic sediments, which constitute the great bulk of the series of which I have spoken, has been the result of successive movements of the earth's crust extending over vast periods of time.

It may, I think, be provisionally accepted that the great series of slates and sandstones of North Gippsland, in which, to the east of the Mitchell River, are situated most of the gold-workings, is of Lower silurian age;* and it is in this portion of the district that Swift's Creek is situated. I speak of this series throughout this paper as Lower silurian, leaving to the future the determination of other local exceptions similar to those to which I have alluded.

At the Upper Dargo River the Lower silurian formations pass within a space of about two miles by the production of mica, and the segregation of silica into mica schist, and by the further accession of felspars into gneiss, and ultimately as the extreme of the series into granite.

These altered rocks constitute a well-marked series of metamorphic schists. There are no intrusive igneous rocks to which the changes I have noted may be due; and an examination of the district shows me that these changes have been the result of what has been termed regional, in contradistinction to contact, metamorphism.

I cannot enter in this paper into a consideration of the regional metamorphic schists of Omeo, and I propose to deal with them at a future time. It will now suffice to point out that, starting from the metamorphic area, the degree of change is found to decrease from some given central point until, as, for instance, at a little beyond Swift's Creek, the schists gradually pass into a series of nearly vertical slates and sandstones similar in general character to those I have spoken of as found at the Upper Dargo River. Thus, south of Swift's Creek the series again assumes at the source of the Nicholson River those characters which I have described as characterising it in the goldfield regions of North Gippsland. The crystalline schists of Omeo are the regionally metamorphosed representatives of the Lower silurian formations.

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* The only localities where fossiliferous beds have been met with are east of the Snowy River—*e.g.*, Guttamurra and Deddick.—See *Report of Progress of Geological Survey of Victoria*, Part III., p. 186.

I have observed, when tracing round the boundary of regional metamorphism at Omeo, the constant recurrence near it of tracts of intrusive granites and felsites, but as yet I have not been able to identify such intrusions within the Omeo schists themselves. So far as I have yet examined, it seems certain that all these granites and felsites are of an age younger than the Omeo schists which they adjoin, and at Bindi, where alone some Upper palœozoic rocks still remain, I have found these latter resting upon them.

It becomes, therefore, an exceedingly interesting, and as regards dynamical and chemical geology, an important question for consideration, what connection there may be between the intrusion of these igneous masses and regional metamorphism. I can now, however, only refer thus briefly to the question, and leave it for future consideration.

The intrusive igneous rocks of Swift's Creek, which I have taken as the subject of this essay, are situated exactly in the passage of the normal Silurian formation into the regional schists of Omeo, and are, therefore, an example of the above statements.

Although it can be shown that these intrusive masses are all younger than the Omeo schists, it is not easy to point out the precise period to which they belong. They are generally found protruding from the denuded Lower palœozoic formations as mountain masses, or when the sediments are hard and silicious, they form eroded basins. At Swift's Creek there are no younger formations to aid in determining the geological age. At Bindi, however, as I have said, at a few miles distance there is a similar occurrence of intrusive igneous rocks which is overlaid by Devonian sediments.* In this instance, therefore, the age is fixed as between the close of the Silurian and the middle of the Devonian periods. Elsewhere similar intrusive masses as Mount Taylor, near Bairnsdale, are found capped by Upper Devonian beds.† The Swift's Creek granites and diorites are, in fact, part of that rock formation of North Gippsland upon which the Upper palœozoic sediments were laid down.

**Report of Progress of the Geological Survey of Victoria*, Part IV., p. 158, *Schedule of Report on Fossil Specimens*, by Professor M'Coy, Nos. 4083 to 4131.

†*The Devonian Rocks of North Gippsland*, by A. W. Howitt. *Report of Progress of the Geological Survey of Victoria*, Part III.; also, *Schedule of Reports on Fossil Specimens*, by Professor M'Coy. *Progress Report G. S. V.* Part IV. No. 2687, p. 155, and No. 3295, p. 156.

(2) Mineral Composition and Classification of the Rocks.

In attempting a description of the mineral composition of the various rock masses met with in the district I am describing, it becomes necessary to begin by a division of the rocks into sedimentary, regional metamorphic, igneous (intrusive) and contact metamorphic, and it is in this sequence that I shall consider them.

(a.) The Sedimentary Rocks.

This class is represented in the area described only by a small tract of yellow and green slates and quartzose sandstones, in the south of Riley's Creek, and by a narrow zone of indurated slates and sandstones lying outside the rocks in immediate contact with the intrusive diorites and granites. These indurated sediments approach the character of the normal Silurian rocks, of which they are, I doubt not, part. In them the effects of alteration are not so far advanced as to remove them from the category of the sedimentary into that of the metamorphic rocks. The examples examined were collected at Tongeo West, Swift's Creek, where they pass on the one side into the hornfels group, and on the other into nodular argillaceous schists, which are there the least metamorphosed of the Omeo series. The changes which are observable in these indurated rocks are to a great extent parallel with those which I have noted in a series of slices prepared from the passage rocks, which connect the normal Silurian slates and sandstones with the regional crystalline schists at the Upper Dargo River. The normal argillaceous slaty members of the series, for example, are seen to be more or less permeated by a pale green to almost colourless silicate, which in places forms distinct flakes or small patches. In more altered examples there are more numerous flakes, and also somewhat short and stout but often ragged fibres of similar character. The most complete change is found in those rocks which precede the distinctly micaceous beds, in which the ground mass of the rock appears to be a colourless transparent mineral in scales or flakes, which are doubly refracting and suggestive of kaolin; and throughout this groundmass there are many—often extremely numerous—pale green interlacing fibres, apparently the representatives of the previously remarked diffused silicate. These suggest chlorite, and so far as can be observed of such microliths, become dark when their longer diameter accords with the polarising plane of either of the crossed nicols. The change in the Swift's Creek passage rocks, or least altered of the contact schists, very strongly resembles that seen in the Upper Dargo passage rocks. The ground mass consists of minute, colourless, transparent, overlapping scales or flakes, probably orthorhombic, and in this, either irregularly disseminated or lying parallel to the bedding, are great numbers of pale green to almost colourless, rather stout, and usually bent and twisted fibres. So far as it is possible to speak with any certainty of such microliths, it seems to me that they become obscured when their longer diameters are parallel with the plane of polarisation of one of the crossed nicols. It seems to me, therefore, probable that the rock-forming materials of these argillaceous strata have become rearranged as two distinct silicates. In the absence of a quantitative analysis of the rock, it is not possible to speak with any certainty; but assuming that these Silurian slaty rocks have a composition similar to that of such rocks elsewhere, and which have been analysed, the idea is not unreasonable that in the colourless, probably orthorhombic, scaly silicate we may recognise a mineral allied to kaolin, and in the pale-green, stout, twisted fibres or plates, a magnesian silicate allied to chlorite. Besides these component silicates there is some amount of amorphous, black, opaque material, unaffected by hydrochloric acid, which may probably be carbonaceous.

Throughout these rocks strings and lenticular groups of quartz grains, as also contorted veins of quartz containing the chlorite fibres (?), indicate metamorphic action.

Classification of the Sedimentary Rocks.—It is not necessary to say much as to the classification of these rocks. That they are sedimentary in origin is shown by their position and structure in the mass. Their probable geological age is indicated by the general considerations to which I have already referred; and the microscopic examination shows that they are the indurated representatives of rocks, such as the fine-grained aluminous slates and the quartzose sandstones of the Silurian formation of the district.

(b.) The Regional Metamorphic Rocks.

The regional metamorphic schists which are found on the north and west side of Swift's Creek include, I believe, almost the whole series, from silky, wrinkled, argillaceous schist to granite. To deal with all such schists as occur within the area I have mapped would be, in fact, to open up the whole question of regional metamorphism, and this is outside the scope of the present paper. I have, therefore, only examined those nodular, argillaceous, and quartz schists which form the fringe of the regional metamorphic area.

In speaking of the component minerals of these rocks, I must include the ill-defined substance which I have already spoken of as forming the main mass of the slaty rocks and the cement of the sandstones.

In a slice of the nodular schist from Swift's Creek, examined under the microscope, the ground mass is entirely composed of plates of mica, which are approximately parallel to each other. As, however, the foliations of mica are more or less contorted, the aggregations of mica plates seen in the thin slice are discordant; some are flat, and some on their edge. The mica plates envelope the nodules, and are, where nearest to them, rather smaller than elsewhere. In treating a thin slice of this rock with concentrated hydrochloric acid for several days, the only perceptible effect was the removal of much iron by which the rock was stained. Among the colourless mica, which I regard as muscovite, are numerous flakes and groups of flakes of dark-brown magnesia mica. These flakes are approximately rhombic in form, are strongly dichroic, although not, perhaps, in so marked a manner as is much of the magnesia mica of the diorites.

There are throughout all this ground mass innumerable minute, thorn-like, dark-brown to black microliths, which cross each other and interlace in the utmost confusion. I observed that the greatest numbers were associated with the magnesia mica rather than with the potass mica. These microliths have often ragged or brush-like terminations, and suggest that they may be built up of a number of fibres. I am unable further to determine what they are, owing to their minute dimensions, but it has seemed to me possible that they may belong to amphibole.*

I have observed several instances of alternation of laminæ of potash and of magnesia mica, and also frequently the inclusion of minute plates of the former in the latter. In the muscovite of the ground mass I observed minute cavities,

* See Zirkel *Mikroskopische Beschaffenheit der Mineralien*, 1873, p. 491.

apparently containing fluid, and also very minute colourless rectangular crystals which I could not otherwise determine.

The nodules contained in the ground mass have the same constitution, but their structure is exceedingly minute. When the edges of the slice are very thin it is possible to make out that they are composed of minute rounded plates of some colourless mineral, having a micaceous structure. This mineral is unaffected by hydrochloric acid. In the ground mass of the nodules the magnesia mica is also developed in isolated aggregates of slightly overlapping laminæ, which are irregularly rounded when seen in the direction of the prismatic axis, but irregularly rectangular across it. They are dichroic, and in several nodules which I examined I found them arranged with the prismatic axis parallel to the shorter diagonal of the nodules.* With these there are also long and narrow flakes of muscovite, and, as before, I found here minute flakes of it embedded in the magnesia mica. In the ground mass there are many minute black opaque and amorphous masses which are probably a form of carbon.

A most interesting, and at the same time puzzling, observation is the frequent occurrence of spheroidal or elliptical cavities, having all the appearance of vacuities—namely, a wide, dark margin and a central spot of light. I have felt much doubt whether these vacuities may not have resulted from imperfect mounting; but as I observe them in almost all the nodules, I have concluded that they may be natural. According to some measurements they are ·0005 inch in diameter. I am unable at present to account more fully for them.

The nodules are portions of the rock mass which have not undergone the complete change to which the remainder has been subjected. They are less crystalline than the ground mass.†

Classification of the Schists.

The examples of these rocks are so few, being only taken from the nodular argillaceous and the quartzose members of the group, that few words are required. An examination in

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* Further examination has shown me that by digestion with warm hydrochloric acid the brown pigment (iron) is removed in a great measure from these nodules. The dichroic mica becomes perfectly colourless, and it only differs in form and in its small optical angle from muscovite.

† Professor Rosenbusch points out similar changes. See *Die Steiger Schiefer, &c.*, Strassburg, 1877, p. 256.

the field suggests that which the microscopic analysis confirms —namely, that they are nodular argillaceous schists and quartz schists; in fact, those members of the regional metamorphic series which are found in many localities near Omeo in the outer verge of the regionally metamorphosed formations.

On the one hand, they are found, as at Swift's Creek, to pass by increasingly altered examples into the true mica schists and gneiss, and on the other by less altered examples, as would be the case at Swift's Creek did the intrusive masses and their contact zones not intervene, into the normal Silurian slates and sandstones.

(c.) The intrusive igneous Rocks—their component Minerals.

The rocks of this class form, as a whole, a great intrusive mass of about 30 square miles in area. They are surrounded by a zone of contact schists, are flanked in the east, north, and west by the regional metamorphic, and in the south by the more or less normal Silurian formations. These intrusive igneous rocks are compounded of various minerals, and it is in accordance with their co-occurrence that the rock masses must be classed. I now proceed to examine their individual mineral constituents, and to record my observations.

The Felspars.

It becomes of great importance, in classifying the felspars, to attempt, if possible, to fix upon some optical characters of sufficient constancy to serve as standards of reference. Such constant characters have been indicated by Des Cloizeaux,* and are frequently referred to by Rosenbusch.† The former states that in thin plates of albite, parallel to the basis, the plane of the maximum obscuration forms an angle with the composition face of 3° 50′ to 4° 50′; in oligoclase that direction is almost parallel to the composition face; in labradorite, the angle is 5° 17′ to 6° 58′, and in anorthite 20° to 40°, when the plate is

* *Comptes Rendus,* lxxxii, 1876; and abstract *Nenes Jahrbuch für Mineralogie,* 1876, p. 658.

† *Mikroskopische Physiographie der Massigen Gesteine,* 1877, p. 14 *et infra.*

parallel to the basis; or in the latter 33° to 46° when it is parallel to the brachypinacoid. He states further that in the triclinic potass felspar microcline the same optical angle is 15° 30′, while in orthoclase the direction of greatest obscuration in basal sections is parallel to the edge formed by the basis and the clinopinacoid.

In order to test these statements I have prepared, and also procured from Germany, a number of slices taken in the direction of the basis and of the lateral pinacoids from both the monoclinic and triclinic felspars. I have, besides making observations upon these type specimens, also measured the required optical characters of all those sections of felspars, which appeared suitable in several hundred thin slices in my possession. The result has been to assure me that these characters may be provisionally used for the classification of the felspars, and to hope that further investigations will give to this method of examination still greater precision and reliability. Following out the indications given by Des Cloizeaux, the following is the standard of comparison which I have used:—

1. Albite and oligoclase: inclination of the optical section in zone o—$\overline{\text{ii}}$ to the edge o—$\breve{\text{ii}}$, 0° to 20°.

2. Labradorite and anorthite: inclination of the optical section in zone o—$\overline{\text{ii}}$ to the edge o—$\breve{\text{ii}}$, 6° to 30° and 20° to 45° respectively.

3. Microcline: inclination of the optical section in the zone o—$\overline{\text{ii}}$ to the edge o—$\breve{\text{ii}}$, 10° to 16°.*

4. Orthoclase: inclination of the optical section in the zone o—ii to the edge o—$\grave{\text{ii}}$, 0°.

In endeavouring to apply practically these indications, it is evidently necessary to measure these sections only which are perfectly, or nearly, in the zone o—$\overline{\text{ii}}$, if triclinic, or o—ii, if monoclinic. In those cases where there was not a perfect accord, the discordance not being greater than 3°, I have taken the mean. By these observations I have found myself enabled to class the felspars I have examined under four heads, as above. I now proceed to consider these classes more particularly.

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* The angle 10° in slices parallel to $\overline{\text{ii}}$ is approximate only.

1. *Albite and Oligoclase.*

Rocks containing felspars, whose angles of maximum obscuration in the zone o—$\bar{\text{ii}}$, as against the edge o—$\breve{\text{ii}}$, point to the above, are found at Lower Riley's Creek, near the Long Gully Gap, at Upper Swift's Creek, and at Eureka.

The principal point to be noted in these felspars is that they are usually compounded of very numerous narrow or alternately narrow and wide laminæ. They occur either as well-formed prismatic crystals having plane or compound terminations, or of much larger size, in which case they are less well defined.

As to the mode of composition I note as follows:—

1. Simply compounded of many alternating laminæ (albite law).

2. Doubly compounded, each half being as in 1, composed of many twin laminæ, or one-half thus compounded, while the other half (right or left) is plain. In this case we may suppose that the compounding has followed two laws—first, that of "axis of rotation normal to $\breve{\text{ii}}$;" and, second, that of "axis of rotation parallel to $\breve{\text{ii}}$;" or, to use expressions which will be very convenient for the purposes of this essay, according to the "albite" and "carlsbad" laws. More rarely there are cases in which the crystals consist of two pairs of twins compounded as above, thus forming a quartet. A third law may there be regarded as being followed—namely, the "pericline law," where the axis of rotation may be considered as the macrodiagonal.

The irregularities of twinning consist principally in the presence of isolated laminæ, or of small associated twin laminæ in otherwise plain sections. In some instances there are also single laminæ across the general composition. In other infrequent cases I have observed a twin dissimilarly compounded, having, for instance, the right half plain and the left half twinned (pericline law) in a direction perpendicular to the composition face.

Together with these undoubtedly triclinic felspars there are many sections which show no trace of twin composition. Some may be orthoclase, but there are others whose outlines are not rectangular but rhomboidal, and yet in which the direction of greatest obscuration is parallel to the larger side. This, I think, directly points to oligoclase; and where such sections are associated with twinned felspars whose optical sections do not form angles above 20° in the zone o—$\bar{i}\bar{i}$, the probability becomes strengthened that the former are sections of oligoclase crystals taken parallel to $\breve{i}\breve{i}$.

In the measurement made of these felspars I find the angles 0°, 6°, 13°, 15°, 17°, 18°, 20°, to be of most frequent occurrence.

It is of interest to note the association of other mineral constituents with this group, and on this point I have endeavoured to gain information by carefully tabulating my data. The results are, of course, only approximate, and as such I give them; in fact, merely as suggestive of the probable truths.

I selected thirty-two slices which I regarded as fairly representing the crystalline granular igneous rocks collected. But in this collection I must note that the granitites and amphibole granites are in a minority, as they did not attract my attention so strongly by their contact phenomena or their auriferous character as did the diorites. Of these I found four in which the predominant felspar came within the requirements of this class. With it were associated subordinately labradorite, mica or hornblende, and quartz.

2. *Labradorite and Anorthite.**

These felspars are found most commonly in the felspathic diorites along the south margin of the intrusive area in the Gum Forest; especially, however, at Riley's Creek and at the Sheep Station Creek Gap. They are usually associated with a little hornblende, or mica, or both, and more rarely with quartz.

Felspars, whose angles of obscuration point to albite or oligoclase, are entirely subordinate where these occur, excepting in one locality near Eureka where I have met with rocks in which the felspars of this group and the former were in nearer proportion.

As the more acid felspars of group 1 increase, so does the percentage of quartz increase in amount in the rock. I have only observed two instances where felspars having the optical angles of this group occurred in company with a preponderance of microcline or of other tricline felspars.

The compounding and general structure of these felspars

* Andesine has been omitted, but there are measurements which cover that species.

are peculiar and interesting. The compound individuals are often seen to be well crystallised; but also, on the other hand the converse is frequently the case.

In some slices the larger individuals are all of imperfect outline. But in all cases the structure is either highly compound or irregular.

The compounding takes place almost always according to three laws, and the lamellæ are disposed most irregularly. The two halves of the twin are rarely even approximately the same in mode of composition. Instances of such structure are given in Figs. 1, 2, 3, 4.

The peculiar structure of these felspars, their broad bands of vivid colour by polarised light, and their optical characters, sharply distinguish them from those of the first group, which, as compared to them, is characterised by regularity of structure.

In this group the smaller individuals are usually most completely formed; but there are many cases where these felspars are only twinned granules, similar in character to the instances figured Nos. 7, 8, 9, 10.

As examples of well-formed crystals I give Figs. 5, 6. The latter is a good illustration of the concentric and not always concordant growth of these felspars.

The rock at Sheep Station Gap, which is mainly composed of these felspars, is almost wholly decomposable in fine powder by cold concentrated hydrochloric acid. In order to apply further tests in the absence of a quantitative analysis I did as follows:—A slice taken from the very felspathic rocks just mentioned showed me only well-marked felspars of this group having angles of obscuration of from 30° to 45°, and with all the peculiarities of structure which I have noted.

I placed this slice for eight days in cold concentrated hydrochloric acid. The felspars were attacked, and became entirely opaque and cloudy. No striations were then visible by polarised light; but there were in two or three cases unstriated or slightly striated margins which had perfectly resisted the action of the acid. There were also a few small felspars in the mass equally unaffected, and in one of which I observed the optical section to be parallel to the longer diameter. These observations point to the felspars being mainly anorthite, with albite or oligoclase, either forming a margin to the former or occurring alone as small crystals. Of the thirty-two selected examples I found twelve in which the predominant felspar belonged to this class, and of these seven pointed to anorthite. The associated felspars with anorthite were labradorite, oligoclase, or even rarely albite; there was usually hornblende, and less frequently mica. Very rarely a colourless pyroxene (diopside) occurred. In only two cases I found quartz. In the five slices in which labradorite probably predominated, the associated felspars were oligoclase and albite, together with hornblende, mica, and quartz.

3. *Microcline.*

Felspars which I have classed thus are found in rocks at the lower part of Riley's Creek, at the Long Gully Gap, at the extreme source of the Sheep Station Creek, and at Eureka—that is, in the quartzose diorites and the allied amphibole granites adjoining the contacts.

The structure of these felspars is usually most irregular, but of an irregularity differing completely from that of group 2. It is an irregularity of structure, both physical and optical. I find these felspars most frequently as crystalline masses of irregular outline, and of larger extent than any of the individuals of the two other groups. It is common that individuals are built up of various incongruous portions, and yet form a whole. Thus, in an example which I give from Riley's Creek (Fig. 11) I found that the imperfectly shaped crystal was composed of three unconformable portions, of which one part was not striated, but had only lines of zonal growth.

In some cases the crystal is composed of two halves (Carlsbad law), one of which may be plain, while the other is striated.

In some cases the crystal is a single individual, but then almost always showing lines of growth.

In other cases, as in a slice taken from a rock at Riley's Creek, I observed, besides these instances which I have noted, where the twin (Carlsbad law) is plain as to one-half and striated as to the other, instances where in a simply compounded individual (albite law) the striations only extended partly down the crystal, and then passed almost insensibly by a curiously-mottled band into the remainder, which was unstriated.* In a somewhat similar example I have

* It must be fully understood that when I speak of the striation or of the optical character of the felspars, polarised light is implied.

observed the striated part to surround a central curiously-mottled and unstriated space. In this case I have noted a cross-banded structure, which is of common occurrence. I give in Fig. 15 a well-marked instance of this characteristic mode of composition.

These felspars do not, as a rule, polarise with those brilliant colours which are seen in groups 1 and 2; but on being rotated between crossed nicols the unstriated and mottled portions, or what may be said in some cases to be the mass in which some few twin lamellæ are situated, shows a peculiar bluish or brownish satiny sheen, which I have found to be highly characteristic of these felspars.

Cleavage is not often observable with any distinctness in these felspars, and their physical structure is otherwise peculiar. Many cases occur where they are fractured—the parts separated, and perhaps cemented together by ground mass. As a rule, they are well preserved, and rather glassy in appearance.

The only inclusions which I have observed are apatite prisms, and needles. The alterations are not great, and have principally produced kaolinisation, and only more rarely mineral aggregates of the mica group. Many of the minute cracks traversing these felspars are the depositories of infiltration products—such as ferric-hydrate.

There are, therefore, among these felspars those which are wholly twinned, or partly twinned, and those which are simple. The angles of obscuration referred to the composition face in slices approximately in the zone $o\ \overline{ii}$, when the individual is compound, are under 18°, and most frequently 14°, 15°, 16°, while in the simple portions the direction of obscuration often conforms with the edge o—$\breve{ii}$, supposing the crystal to be triclinic or o—$\grave{ii}$, supposing it to be monoclinic. These angles do not agree with the triclinic soda and soda lime felspars, nor with orthoclase.

Des Cloizeaux has pointed out* that the triclinic potash felspar microcline is sharply marked by its characters. A slice parallel to the basis shows the direction of obscuration inclined to the edge o—$\breve{ii}$ at 15°—16°, instead of being parallel to it, as in orthoclase. Many of the microcline group—as, for instance, Amazonstone—are distinguished by two systems of

* *Comptes Rendus*, lxxxii., No. 16; also see Rosenbusch *Mikroskopische Physiographie der Massigen Gesteine*, 1877, p. 14.

lamellæ, whose intersection is nearly perpendicular, and in which the alternate lamellæ are twins. This structure of microcline produces a highly characteristic cross-banded appearance by polarised light.

The observations which I have made on these triclinic felspars entirely accord with the above, and although a quantitative analysis of the rock is still required, I feel that I may with some little confidence refer these felspars, as I have done, to microcline. I shall have to point out later in this essay that the felspar composing one of the contact schists is without doubt a triclinic potash felspar, and that it agrees optically with the above requirements of microcline; it also agrees in its character with the felspars, which are components of those rocks which adjoin the schist.*

The inclusions in these felspars are few in number as in species. Apatite in small colourless prisms and needles is the most frequent. In some few cases I have observed microscopic flakes of magnesia mica, or of amphibole, and also minute, colourless, rather stout prisms, whose terminations suggest a monoclinic habit. Very rarely I have observed what appear to be octahedral crystals of magnetite. Besides these, which may be regarded as original inclusions, there are also frequently flakes of chlorite and patches of iron ores, evidently the result of alteration and infiltration.

The alterations which these felspars have undergone are of two kinds, of equal frequency of occurrence—kaolinisation and micacisation. In both cases the change has mostly commenced from the centre and extended outwards along the cleavage planes. But occasionally I have observed that some lamellæ have been more affected than others. When the felspar has been kaolinised it becomes grey and cloudy, and loses its characteristic chromatic polarisation, without

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* I may note that I have, as yet, failed to isolate these felspars. As an instance, I may take the following :—I obtained a fragment from the perfect cleavage of a crystal apparently of this felspar in one of the coarse-grained samples which had afforded me a characteristic thin slice. From part of this I succeeded in preparing a microscopic object; the other part I examined before the blowpipe for potassium. The microscopic examination proved it to be not striated, and that the direction of obscuration was parallel, or nearly so, with the edge $o - \breve{ii}$ (supposing it to be triclinic). The portion examined chemically gave only a very slight precipitate of chloride of platinum and potassium. Before the blowpipe I could not detect potassium with any certainty by observations of the flame reaction through cobalt glass. The above experiments point, I think, to a simple crystal of oligoclase.

acquiring any other marked character. When the felspar has been converted into a micaceous mineral the result is an aggregate of minute twisted and crumpled, colourless plates, which with crossed nicols polarise with much colour. When these flakes are more regular and somewhat of larger dimensions than usual I have been able to observe that they narrowly resemble muscovite. As, however, both the potash and the soda lime felspars are similarly altered, the idea suggests itself that the resulting mineral may be either a potash, a soda, or a lime mica, according to the constitution of the felspar. This micaceous alteration may be observed in every stage, from a small central aggregate of mica scales to the complete conversion of the whole felspar crystal.

4. *Orthoclase.*

The monoclinic potash felspar is found in rocks in that part of the area east of the Gum Forest where the granitic rocks are the representatives of the intrusive masses. It is also found in the quartzose diorites of Riley's Creek and Swift's Creek as a subordinate constituent.

It is rarely well crystallised in the quartz diorite, but generally occurs as irregularly bounded masses or imperfect crystals. In some cases it forms a more or less essential part, and thus causes such rocks to approach in character to the granitites and amphibole granites of the fall to the Tambo River in which it predominates. It is more subject to alteration than the triclinic felspars (including microcline), and the alterations are to kaolin as well as to mica.

Inclusions are rare, and confined almost to apatite and to a little magnetite. As the diorites become more basic in constitution, orthoclase decreases in amount, until, as in the anorthite diorites of Riley's Creek and in the amphibole-gabbros of the Gum Forest, it is entirely absent. I have found it always associated with quartz, with either hornblende or magnesia mica, or with both together, in company with the felspars of groups 1 and 3.

In addition to these rock-forming felspars, I have met with one which is a constituent of a mineral vein at Power's Reef, near Eureka. This reef is immediately in the contact, and the vein mentioned passes through the quartz diorites, and consists of two felspars, quartz, and broad plates of dull-green magnesia mica. One felspar is pale flesh-red, and has all the appearance of orthoclase. The other is milk-white, and in it, so far as I could observe in the absence of measurements, the two most perfect cleavages are not quite perpendicular to each other. The basal cleavage reflects light in numerous planes very slightly inclined to each other. The lustre in this cleavage is slightly more pearly than in orthoclase. Samples examined before the blowpipe gave strong potassium flame and moderate sodium flame reactions, and a quantitative examination showed a considerable amount of potassium. Pieces from the basal cleavage, examined as thin slices, proved to me that this felspar varies much in structure. In one example, half, at least, shows the usual characters of orthoclase in which the internal structure is not quite homogeneous. The other half is traversed by irregular bands of triclinic felspar, in which the composition face is across the direction of the bands. The angle of obscuration in these bands is from 2° to 3° on each side of the composition face. The portions alternating with these bands of triclinic felspar become obscured in a direction, according to my measurements, which were not quite satisfactory, of 14° against the edge o—ii, supposing the felspar to be orthoclase. This ground mass is always more or less cross-banded, precisely in the manner of Amazon stone; and where this structure was well developed, I obtained some measurements of the angle which gave me 15° 30′. This indicates microcline.

A second piece, prepared from a sample which had the discordant cleavage planes on the basis, showed me that the whole was traversed by very narrow and somewhat faint lines of twinning. In places, however, where I could obtain measurements I found that portions became obscured when the plane of polarisation of one of the nicols was parallel to the composition face, while other lamellæ required to be rotated over an angle of 3° with that direction before becoming obscured. These observations indicate that the first example has the structure of perthite, with this difference, that potash felspar is in its triclinic form. The second example appears to consist of alternating lamellæ of albite and orthoclase.

A sample of the pale red coloured felspar prepared from the basis showed only the cross-banded structure characteristic of microcline.

This felspathic vein is one of a numerous class which occur in the Omeo district, traversing the crystalline schists.

They belong to the "endogenous granite veins" of Dr. J. S. Hunt. They, almost without exception, have this cross-banded or twinned variety of sodiferous potash felspar.

It was, I think, formerly assumed that the triclinic felspars which are constant constituents of the granites, belonged to oligoclase. This also applies to the triclinic felspars of the quartz diorites, their near allies. It was also generally assumed that two or more of the triclinic felspars did not occur together in any one of the igneous rocks. These views have gradually been abandoned. Indeed, if we accept Tschermak's theory that the various felspars, albite, oligoclase, andesine, labradorite, anorthite, are, in fact, but an iso-morphic series, of which the second, third, and fourth are admixtures of the first and last, there can be no real difficulty in accepting as probable that any two or more of them might occur together, in accordance with the various proportions of potass, soda, or lime in the original magma. Assuming the correctness of Des Cloizeaux's statements, and that the observations which I have made are reliable, we have, then, proof in these Swift's Creek rocks of such simultaneous occurrence. I have pointed out the general groups into which I have found it possible to collect the felspars, and these groups probably include the whole series. I observe that in the series, orthoclase, microcline, albite, oligoclase, anorthite—taking these five as an illustration—the more basic the felspars are, the less free quartz is associated with them in the rock. It becomes evident that in the quartz diorites of a very granitic character, microcline in a great measure represents the triclinic forms. It is associated not only with its then subordinate monoclinic form, orthoclase, but also with those felspars, the inclination of whose direction of obscuration to the composition face point to albite or oligoclase rather than labradorite or anorthite.

All these and other considerations have led me to see that our usual view of the felspars will probably undergo considerable modification. We can no longer view them as a group of distinct species, but as forming a series of iso-morphic mixtures of certain double silicates of alumina and alkali, or lime, or baryta, in which some particular ratios of the components most frequently occur. It is, in fact, only in accordance with the theory of the felspars as propounded by Tschermak that a comprehensive view of the whole group becomes possible. He has shown that the triclinic felspars are iso-morphic silicates of alumina and alkali, or of alumina and lime, or baryta. The felspar in which the alkali is potash, is as orthoclase monoclinic, while as microcline it is triclinic. The felspar in which the alkali is soda is only known in its independent form as the triclinic albite. But the admixture of soda which is constantly found in varieties of orthoclase, such as adularia, in which it evidently does not exist as an intergrowth of albite, proves that in these cases it must be present as an iso-morphic mixture, and we have then the soda felspar albite in its monoclinic form. Similarly the small percentage of lime in orthoclase, or of potash in albite, or in anorthite, points to iso-morphic admixture of the potash, soda, and lime felspars. The baryta felspar is not known in independent existence, but hyalophane "is a mixture of potash felspar with that barium compound which in its composition is the analogue of the lime compound anorthite."*

These facts indicate that the whole of the felspars are an isodimorphic series. Such series are not rare in nature. I may instance the anhydrous carbonates of the iso-dimorphic calcite and aragonite groups.

Amphibole.—Throughout the whole area examined amphibole in some variety forms an essential constituent in the majority of the examples which I have collected; but in the central and southern parts of the great intrusive mass it occasionally predominates to the exclusion of almost every other mineral. In forty slices which I have taken as representing the general composition of the intrusive dioritic masses, I find that it occurs as an essential constituent in nineteen. In two of these it forms almost the whole bulk of the mass; in six it is merely accessory to the magnesia mica, and in five it is absent; in three cases only does it occur in rocks devoid of free quartz. I find it in these examples to be associated with the felspars of groups 1 once, 2 seven times, 1 and 2 ten times, 3 and 4 nine times, and 1, 2, 3, and 4 once—thus showing a slight preference for the lime and soda lime felspars rather than the potash felspars.

Amphibole occurs in more than one variety. In the granitic quartz diorites it is in more or less ill-defined, short, prismatic crystals, or in irregularly shaped plates; in those

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* *Tabellarische übersicht der Einfachen Mineralien, &c.* P. Groth, Braunschweig, 1874. I am under many obligations to this admirable review of the mineral kingdom.

more basic rocks, of which it forms a large ingredient and wherein quartz is absent, it occurs either in ill-defined prisms or in large crystalline masses which often have a predominant cleavage apparently in the direction $\overline{\text{ii}}$. The colours and structure of these two varieties also differ. The former are often glassy in appearance, and yellowish or dark-green in colour; the latter are in shades of green, often very pale, and in some cases redish-brown. In the latter it is almost invariable that they include exceedingly numerous, imperfectly-formed crystals of plagioclase, whose outlines are usually rounded as if from incipient re-solution. There are also numerous spheroidal masses of what seem to have been "ground mass."

It is almost always possible to trace prismatic cleavage in some of the sections across the prism, excepting in those crystalline massive varieties which form almost the whole rock mass, and in these it is often very obscure, or even absent. I shall refer to this again in describing the extreme form of this rock. In all cases which I have observed, even in those which depart most from the usual appearance of hornblende, the slices are dichroic, and this character decreases with the diminution of the depth of colour and with the increase of the angle of obscuration of the slice. In those varieties which are crystallised in more or less well-marked prisms, and which are glassy in appearance and somewhat dark in colour, the angle of obscuration, according to a number of measurements in slices approximately parallel to $\grave{\text{ii}}$, were from 11° to 16°; while in the second class of amphibole, which was usually in plates or in crystalline, cleavable masses, having lighter tints of colour, the angles measured were very high, being from 17° to 30°. These angles, the faint dichroism, and the marked cleavage in the ortho-diagonal direction, would lead to a suspicion of diallage, but in many cases I was able to observe the prismatic cleavage of hornblende. In the former class twinning, according to the usual hornblende law, was not very frequent; and I found one instance where there was no trace of the prismatic cleavage, while yet the prism itself had the angles of hornblende, and not of augite. In the second class of amphibole, twinning is still rarer. Among the few peculiarities of structure to be noted is one which I have frequently observed in the hornblende of other rocks—as, for instance, of the hornblende porphyrites of Bulgurback.

It is that in many of the prisms there is a nucleus of what I believe to be crypto-crystalline ground mass, round which the hornblende individual has crystallised. This is, therefore, quite different to those inclusions of small spherules of ground mass which so often are seen in the massive cleavable varieties.

The principal inclusions in these two varieties of amphibole are prisms of plagioclase and crystals, and masses of magnetite and pyrite, and more rarely flakes of magnesia mica. The included felspars are usually of very abnormal structure, the twinning taking place in unusual modes. The crystals are usually imperfect, the edges rounded, or the sides unequal in dimensions. There may be only one, or, again, a considerable number of striations, and these striations are sometimes not continuous throughout the slice, or may be confined to one-half, or be of different directions in each half, or finally be represented by imperfect laminæ or flakes only. Many of these felspars have undergone serpentinous (?) alterations, together with or independently of the hornblende. There are other inclusions which I am unable to identify with anything else than portions of crypto-crystalline ground mass, which has been included. As I have said, these latter are often present as cores of hornblende prisms, and then are found usually to conform to the rhombic outline of the cleavage.

The most usual alterations to which the hornblende has been subjected is to some form of chlorite. The first appearances of change are that the edge of the hornblende becomes ragged and fibrous. The fibres are dichroic, in shades of pale-yellow and bright emerald-green. In further instances the hornblende is found to be wholly changed, with the exception of a small portion, so that by such various instances we are led to perceive the origin of similar masses of chlorite where no traces whatever of hornblende remain. In order to determine whether this chlorite is fibrous or scaly, I have carefully traced round those examples which occurred in the margins, and, therefore, in the thinnest part of the slices, and I have there observed that the chlorite fibres are approximately paralleled, are not of equal length, and are, therefore, overlapping. In places the observations suggest that these fibrous appearances are due to the sections being across plates or scales having a fibrous structure; and the very thinnest portions, examined with a high power, appeared, indeed, to consist of minute pale-green and translucent twisted fibres.* In one slice I found somewhat larger plates of this mineral, of a darker green colour, and so situated that I was enabled to make stauroscopic observations, from which I inferred that it was certainly uniaxal. I therefore conclude that this alteration is chlorite, and have thus spoken of it. It is easily decomposed in the slice by warm hydrochloric acid.

In the production of these masses of chlorite the original form of the hornblende becomes totally lost. These observations lead me to doubt whether any of the masses of chlorite which so frequently are found filling in spaces and lying between various constituents are in any case contemporaneous constituents of the rocks, but rather in all cases derived from the alteration of amphibole, and more rarely, as I shall point out, of magnesia mica, as well as still more rarely of pyroxene.

The production of chlorite has in all cases also given rise to the elimination of ores of iron which have been deposited either in the cleavage of the chlorites, or in cleavage or flaws in the neighbouring constituents, or between them.

A second form of alteration I have observed to arise more frequently in the second variety of amphibole. It much resembles in appearance the talcose pseudo-morphs after hornblende which I have obtained from an amphibolite dyke near Omeo. The extreme forms of alteration in the Swift's Creek rocks have much similarity to serpentine. The first appearances are a lessening of colour, the production of a fibrous structure, and the deposit of iron ores. Further changes result in an aggregate of brightly polarising particles, irregularly or divergently disposed. Figs. 21, 22, are given as illustrative of the above statements.

Amphibole-anthophyllite.—This mineral is of only local occurrence at the Gum Forest, where it forms almost the whole rock mass. It extends over many acres of ground. It is crystalline massive, of a dark green colour, showing a perfect cleavage in one direction, having a metalloid and somewhat vitreous lustre. Under the microscope, by ordinary transmitted light it is green, or more rarely brown, in colour;

* These chlorite fibres differ somewhat in aspect from those other chlorite fibres which so largely make up the mass of the indurated rocks of which I shall speak later on. These latter, where occurring singly, often strongly recall prochlorite in its vermicular shape, as seen in quartz from the less altered contact schists of Beechworth.

and these colours are somewhat lighter than is usual in the hornblende of the district. In those slices which are parallel to the most perfect cleavage there are only faint traces of cross cleavage; in those perpendicular to this direction the cleavage in one direction is well marked; less well marked are irregular directions crossing it. More rarely I have met with sections which showed a very imperfect prismatic cleavage, approximately near to 124° 30′. The angles of inclination of the principal optical section against the direction of the most marked cleavage (*i.e.*, against the direction of the axis c), are higher than is usual in hornblende. My measurements gave me, for those sections showing a well-marked cleavage, 12°—22°, and in one instance 26°. The sections of this mineral are moderately, and even occasionally strongly, dichroic, in spite of the rather light tints of the mineral.

These observations indicate a monoclinic mineral, occurring in irregularly bounded crystals, having a perfect cleavage parallel to $\overline{\text{ii}}$, with a metalloid and vitreous lustre, a less perfect cleavage parallel to I, and an imperfect cleavage parallel to $\overset{\diagdown}{\text{ii}}$. Its monoclinic optical characters, its polychroism, and its prismatic cleavage near 124° 30′, refer it to amphibole, while its physical character and its marked cleavage in the direction $\overline{\text{ii}}$ point to anthophyllite. I therefore refer it to that mineral sub-species which Des Cloizeaux has termed amphibole-anthophyllite. I have observed an interesting parallel between this mineral and the pyroxenic mineral diallage. It may be said that this amphibole-anthophyllite stands in the same relation to amphibole that diallage does to augite.* The inclusions in this mineral are peculiar. They may be regarded as constituents of the rock of which amphibole-anthophyllite forms almost the whole; but it will be most convenient to deal with them in this place.

Orthorhombic Pyroxene—A mineral which I refer to this group is in imperfect crystals, or in masses of crystalline granules. It is found between the cleavable masses of amphibole rather than in them, and conforms to their outlines. Macroscopically, I have observed it to be of a rather light clear brown colour, having a resinous lustre and a marked cleavage,

* Anthophyllite is to amphibole as enstatite is to augite. Rosenbusch *Mikroskopische Physiographie der Massigen Gesteine*, p. 263.

the lustre of which is somewhat vitreous. It becomes transparent in the thin slice, and is then either colourless or faintly reddish. It is remarkably fresh and unaltered, and is free from inclusions. Most usually the sections show a longitudinal somewhat perfect cleavage; occasionally a slightly undulating, finely fibrous structure; rarely (and this seems to be in sections across the former) a prismatic cleavage of nearly 90° and two pinacoidal cleavages, of which one is more perfect and the other less perfect than the former. The plane of vibration in the longitudinal sections is parallel to the cleavage, and in the cross sections diagonal to the prismatic cleavage. Absorption is not marked, but the mineral is still polychoic. In the longitudinal sections the dichroism is in light shades of red to colourless; in the sections across the prism in light shades of red and pale orange red. These observations indicate an orthorhombic mineral, having a perfect cleavage according to one pinacoid, a less perfect prismatic cleavage of nearly 90°, and a least perfect cleavage according to the other pinacoid. Assuming the most perfect cleavage as parallel to $\breve{i}\breve{i}$, the axis colours would then be as follows:—$\breve{a}$, pale red; $\bar{b}$, pale orange red; $\acute{c}$, grey or colourless. The mineral is not affected by boiling with hydrochloric acid. These observations agree exactly with the characters of hypersthene as given by Rosenbusch and Des Cloizeaux; but I have not observed the microscopic plates which are generally regarded as characteristic of it. The optical characters of this mineral place it in the enstatite-hypersthene group; and the question arises—"Have we a dichroic enstatite, or a hypersthene without the microstructure of that mineral as found at Isle St. Paul? I should decidedly reply in the affirmative to the second part of the question, for the pleochroism cannot be due to inclusions, but may result from the composition of the mineral."* I may note here that the only other mineral which might be indicated by the orthorhombic character of this species would be andalusite. But the red ray in this case is $\acute{c}$, so that thin slices perpendicular to the prism remain colourless when tested by the polariser alone. A second constant inclusion in the amphibole-anthophyllite is *olivine*. It is found invariably as rounded or elliptical grains. In the thin slice seen by ordinary light they are colourless, free from inclusions excepting

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*Rosenbusch, *Op. Cit.*, p. 479.

rarely magnetite, and have a somewhat rough-looking surface. A net-work of cracks traverses them, which are filled by magnetite. Similar irregular cracks radiate from these inclusions and connect one with the other. This mineral polarises in bright shades of red and green, and has some general resemblance to quartz in its chromatic effects. Not one instance afforded me any outline from which the crystallographic system could be deduced. The general appearance, structure, and chromatic polarisation suggested olivine, and this is confirmed by the mineral being readily attacked in the slice by hydrochloric acid. After a little time, when thus tested, particularly if heat is applied, these inclusions become opaque, and remain dark when rotated between crossed nicols. The whole of the magnetite is also removed from the network of cracks. It is remarkable, however, that few, if any, traces of serpentinisation are apparent. These inclusions of olivine somewhat resemble similar ones which I have observed in a sample of gabbro from Volpersdorf. A third inclusion belongs to the *spinel* group. Scattered irregularly throughout the whole mass, but I think almost wholly in the amphibole, are many grains and masses of grains of irregular outlines, and when of sufficient tenuity having a rich green colour. Very rarely I have observed instances where these grains were rectangular—*i.e.*, in sections of the regular octahedron. When examined in a thin slice ready for mounting by reflected light, these grains are seen to stand above the surrounding mass and to be black and lustrous. As tested by a needle-point, I estimate their hardness as over 7. They are wholly unaffected by hot hydrochloric acid. By transmitted light the grains are, where sufficiently thin, translucent and of a rich green colour. Between crossed nicols, and also examined by the stauroscope, they prove to be isotropic. These physical and optical characters point to one of the spinel group, either picotite or pleonaste. *Pyrite* occurs sparingly throughout this rock in grains. It is macroscopically visible, and in the thin slices may be identified with those opaque black masses which remain after the *magnetite* has been removed by hydrochloric acid.

The alterations which have taken place in this amphibole-anthophyllite commence by the production of a fibrous structure parallel to the axis c. This destroys the glassy aspect of the perfect mineral, but does not alter its monoclinic optical character. I have observed round the edges of the plates and perpendicular to them a more or less wide margin of colourless overlapping fibres. Some alterations have produced aggregates of colourless scales which have a strong resemblance to talcose pseudo-morphs after hornblende,* such as I have observed elsewhere. Connected with these alterations and throughout the altered spaces patches of iron ore (magnetite) have been deposited either irregularly or between the fibres, and similar deposits have been made in irregular branching cracks which traverse the whole mass. The alterations, as might be expected in such essentially magnesian minerals, are rather serpentinous and talcose than chloritic.

Here and there throughout the mass I have observed what seem to be alterations of some original mineral constituent. They are very finely fibrous, the fibres being strictly parallel to each other. They are faintly yellow and dichroic. Optically the plane of vibration accords with the direction of the fibres. Unless these are allied to chrysotile I am unable to suggest their nature.

Pyroxene.—This mineral species is very rare, and I have only found it in the massive very hornblendic diorites of the Gum Forest; very rarely in the coarse grained granitic diorites of the lower parts of Riley's Creek, and in the amphibolite dykes. It is invariably almost colourless in the thin slices or only faintly yellow or brownish yellow. It has the character and cleavage of augite. The angles of obscuration in the slices I find to be 30° to 44°; none of the slices are sensibly dichroic. It occurred, without one exception, in more or less imperfect crystals having the form of augite.

The alteration of this pyroxene has produced an almost colourless chlorite otherwise similar in character to that I have found elsewhere derived from hornblende. It is rather broadly fibrous, wavy, and but faintly dichroic. Iron has been separated either from it or from the associated hornblende, and deposited either between the chlorite fibres or in separate masses either as magnetite or as ferric oxide, in which case it is often bright red and translucent. I have also observed under favourable circumstances that the chlorite is often formed of minute, thorn-like fibres, which are either arranged approximately parallel or else as slightly

* These apparently talcose alterations are not affected by hydrochloric acid.

divergent tufts. Such needles often border the edges of hornblende.

Such a colourless pyroxene, having the form and optical properties of augite, would be diopside.

Mica.—Magnesia mica is the only one found in these rocks. It occurs as an essential constituent in the dioritic and granitic rocks at Riley's Creek, at Upper Swift's Creek, at Eureka, and generally in the fall from the various gaps at Upper Riley's Creek towards the Tambo. On examining the forty slices which I have selected as presenting an average of the whole, I find that it occurs with felspars of group 1 three times, with 1 and 2 twice, with 2 once, with 1, 3, and 4 thirteen times, with 2, 3, and 4 once. Magnesia mica, therefore, may be said to show a preference for the potash felspars, microcline, and orthoclase, and in a less degree for the soda felspar albite. In the one instance when it occurs in company with anorthite, it differs somewhat in its characters from those usually seen. Magnesia mica is most frequent in those rocks which lie on the outskirts of the intrusive mass, and more especially near the contact, when there is a distinctly gneissic structure.

It is not met with as crystals, but as masses or aggregates of bent, twisted, or divergent flakes. It occurs either as disseminated flakes, or as filling in between the various constituents, or enveloping the felspars; when associated with hornblende it is often intimately connected with it by intergrowth.

This mica is usually brown or reddish-brown by light transmitted in the direction of the chief axis, and when examined in a direction perpendicular to this by the polariser alone it is strongly dichroic, the dfference in the colours being pale straw-yellow to almost black. Almost all this mica is optically binaxal, but I have observed a few instances where the mica was, so far as I could observe, uniaxal, or binaxal with a very small angle; and in the slices where this mica occurred I could observe distinctly that one or two minute isolated flakes had hexagonal outlines. I have, however, only met with this in the close-grained micaceous portions of the massive quartz diorites of Riley's Creek, and in the crystalline granular compounds of felspar and mica which constitute the fine-grained parts of the massive quartz diorites of Eureka. Examined stauroscopically the flakes were either uniaxal, or the angle was so small that the disturbance of the cross was barely perceptible.

One variety of the binaxal magnesia mica I have found to be peculiar to the anorthite diorites of the upper part of Riley's Creek and of the Sheep Station Creek Gap. It is red by transmitted light, and has a peculiar coppery sheen by reflected light. It is strongly dichroic in shades of yellow to dark red and almost black. It is decidedly binaxal. It occurs in slightly divergent groups between the felspars, and also intimately intergrown with hornblende. (Fig. 23.)

The inclusions which I have observed in the magnesia mica are almost wholly apatite and magnetite. The former is found to penetrate the various plates, and, in some instances, assuming the form of the mica to be rhombic, to be arranged parallel to the prismatic sides. Very rarely I have observed minute plagioclase prisms, amphibole particles, or portions of ground mass, but such occurrences are very exceptional.

These micas are extremely well preserved, and only rarely show signs of alteration or decomposition. The alterations produce a substance which I cannot distinguish from the chlorite resulting from the alteration of hornblende. In places the whole of the mass of mica plates has been altered, while elsewhere the changes have affected only individual plates.

Figs. 24, 25, are given to illustrate the above statements.

Titanite.—I have only rarely been able to identify this mineral, even after very careful and special examination of those examples in which it might be expected to be present. Most commonly it is in crystalline grains, associated with hornblende or magnesia mica.

Apatite is of very common, almost universal, occurrence in the diorites, and, I think, especially in those which are most granitic in character. I have not observed any special features to note.

Magnetite.—I have already referred frequently to magnetite, and I may now only add that much of that seen is probably of secondary origin, and due to alteration of amphibole, magnesia mica, and, in a less degree, of pyroxene.

Pyrite occurs here and there in the more basic diorites, and especially in the neighbourhood of the mineral veins. In the former cases it is most frequently found in granules, in the latter crystallised in modified forms of the cube.

In many cases, and especially in those quartz diorites in which magnesia mica is a constituent, I have observed, interpolated among the mica plates, mineral aggregates of a pale-yellow or brownish-yellow colour. They have a somewhat rough appearance of surface, and are sensibly dichroic. They show minute aggregate polarisation in bright shades—mostly greens and reds. It seems to me most probable that this mineral is an alteration product. I have found similar aggregates filling in spaces or adjoining the felspars, in one case surrounding hornblende. It has suggested itself to me that this may be epidote, or in some cases even epidosite.

Classification of the Igneous Rocks.

All these rocks are intrusive, and in nowise contemporaneous. The following classification may be made:—

Granites.—This group is confined to the eastern part of the intrusive area, as, for instance, the Long Gully and the Sheep Station Creek. Its members are all of a quartzose character. The predominant felspar is orthoclase, which is usually in crystalline masses, but is also met with crystallised. Potash felspar also occurs in its triclinic form microcline. Plagioclase is always more or less present in well-formed prismatic crystals. Magnesia mica is very constantly present, but is occasionally almost wholly replaced by hornblende, while elsewhere both are found together. Here, then, we have granitite as the prevailing rocks of this class, and also an amphibole granite with varieties connecting the two. Where a large amount of plagioclase is present, there is a passage to the adjoining quartz diorites.

Quartz Diorites.—Rocks of this class are found adjoining the granitites, as at Riley's Creek, or in the outer parts of the intrusive mass, as at Eureka and the upper part of Swift's Creek. Quartz is often a marked constituent, in which case the rock assumes either a strongly gneissic or granitic character. It is most usual, however, for the triclinic felspars to predominate ; and out of twenty-four slices which I selected as representing this class (all of them containing quartz as an essential constituent) I found that one contained felspars of group 1 ; five of groups 1 and 2 ; two of group 2 ; one of groups 2, 3, and 4 ; and sixteen of groups 1, 3, and 4. I have to remark again that the most quartzose rocks are those which contain the potash and soda felspars ; while those which contain the lime felspars are almost or wholly quartzless.

In addition to the quartz and felspars, hornblende and magnesia mica occur either singly or together. In the gneissic rocks of this class (plagioclase gneiss) of Riley's Creek, mica predominates almost entirely to the exclusion of hornblende. But when microcline represents the triclinic felspars, I find both. In addition, the accessory constituents are apatite, titanite, magnetite, and pyrite. These rocks are, therefore, *quartz diorite* and *quartz mica diorite;* and they are connected by those rocks which contain both hornblende and mica.

It must be noted that a rock composed of quartz, a potash felspar, and hornblende or mica, would be a granite; but as the distinctive feature of the quartz diorites is that their felspathic constituent is triclinic, I have considered those granitic rocks in which microcline is the felspar to be a peculiar form of quartz diorite, to which class they are in position more nearly allied than to the adjoining granites.

Diorites.—The true diorites—that is, rocks composed of a triclinic felspar and hornblende, or of those minerals together with mica—are found at Riley's Creek, Sheep Station Creek Gap, Upper Swift's Creek, and Eureka, and are all, so far as I can ascertain, subsequent in age to their more acid allies. The two constituents, plagioclase and hornblende or mica, vary much in their relative proportions; so that on the one hand there results a crystalline granular felspar rock with a little hornblende or mica, and on the other a crystalline or crystalline granular hornblende rock with a little triclinic felspar; but so far as I have observed, mica does not anywhere, like amphibole, preponderate to the exclusion of the other constituents.

It seems that when the felspar predominates it is principally anorthite with a little and very subordinate soda lime felspar (albite, or oligoclase), and the associated magnesia mica a phlogopite; when the hornblende predominates, the felspars are probably albite, oligoclase, labradorite, or anorthite, and in extreme cases are almost invariably only present as imperfect crystals or granules in the amphibole. These rocks would, therefore, be varieties of *diorites,* varying in character from a compound nearly approaching *amphibolite* to one which on account of its felspar being anorthite would be allied to *corsite.*

Amphibole-gabbro.—I have found adjoining those varieties of diorite in which hornblende predominates most, an intrusive mass, seemingly latest in age of all, and which is almost wholly composed of a mineral which I have referred to amphibole-anthophyllite. I have already so fully described the characteristics of this rock-forming mineral, and also of the associated mineral species, that but little remains to be said excepting to indicate the position which it seems to me should be assigned to the rock itself in the petrographic system. It has many resemblances to gabbro, but the departure from gabbro is in the occurrence of an amphibole mineral instead of diallage. Many of the normal gabbros are characterised by a preponderance of a monoclinic pyroxene, having a pinacoidal cleavage, associated with an accessory orthorhombic pyroxene. This abnormal gabbro has preponderating monoclinic amphibole having a pinacoidal cleavage, and has an accessory or orthorhombic pyroxene. For such a compound a special name is still wanting, and the most appropriate, although cumbrous, one would be amphibole-gabbro.* Such a rock stands to diorite much as the normal gabbro does to diabase and melaphyre.

(d.) Dykes.

In speaking of the dykes of the district, I have found it most convenient to depart somewhat from the general plan of this essay, and to describe each of the classes from typical instances rather than to enter first upon a description of the component minerals.

The dykes of the district include the classes felsite, diorite, and diabase. The former are met with in the eastern part traversing the metamorphic schists, and their age is quite uncertain. A few also occur throughout the western part of the area described. They are often granular and quartzose, and are then often much decomposed, and generally have a resemblance to the dykes of granular felsite common in the neighbourhood of Omeo. Elsewhere, as at Sheep Station Creek and the lower part of Riley's Creek, they are compact, hard, grey or bluish in colour, and seem externally but little affected by the agencies which have decomposed the adjoining granites or diorites. The diorite dykes are met with most commonly in the tracts surrounding the intrusive area, but also traverse parts of it, as, for instance, the quartz diorites

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* Streng has described a hornblende-gabbro from Duluth, U.S.A. See *Neues Jahrbuch*, 1877, p. 113.

and gneissic diorites at Lower Riley's Creek, and on the hills between that place and Long Gully and the hills near Eureka. Diabase is rare, and so far seems only to occur at the lower part of Swift's Creek in the altered schists.

Compact Felsites.—Dykes of this class occur only, so far as I have observed, at the source of the Sheep Station Creek, and not far from the intrusive masses of anorthite diorites. They traverse the granitic rocks at that place in directions approximately north-west and south-east, the dip, if any, being probably to the south-west at a high angle.

Slices were prepared from four large parallel dykes, occurring within a distance of about twenty chains, and from six to twenty feet in width. The appearance of the dyke-stone was in each case felsitic compact, of a greyish or bluish grey tint, and seemingly much less affected by atmospheric influences than the enclosing granitic rocks.*

Three of these dykes as examined in thin slices formed a series differing only in the relative minuteness of the mineral components. In one the structure is so minute as to be almost crypto-crystalline. In it, however, faint traces of minute felspar prisms are visible, with some few porphyritic crystals of the same. Here and there are small patches of a dichroic viridite, but the amount is small.

The second sample has a crypto-crystalline, grey coloured ground mass, in which are many minute plagioclase prisms, and fibres and patches of viridite. In this are elongated larger prisms, having the form usual in plagioclase, as also some iron ore (probably magnetite).

The third example has a micro-crystalline ground mass, composed, apparently, of felsitic particles, a little quartz and viridite, both diffused in fine particles, and as flakes and fibres. In this ground mass are—(1) Rather long and narrow interlacing or approximately parallel prisms, having the habit of plagioclase, (2) minute aggregate of some micaceous mineral, (3) magnetite, (4) quartz grains filling in spaces, (5) much viridite in patches.

In all these examples the felspar has been completely altered to minute aggregates of some micaceous mineral; no striations remain anywhere visible. Their form, however, is exactly that of plagioclase. The rock itself has evidently been much altered. The viridite (chlorite ?) may be referred

* These granitic rocks are intermediate in composition between amphibole granite and quartz diorite.

to the alteration of amphibole. The general character of the rock, the proximity of the dykes to the intrusive anorthite diorites, their non-occurrence elsewhere, point to their being a plagioclase felsite.

The fourth dyke examined is of a very finely granular, approximating to a compact, texture. It has a crypto-crystalline ground mass of minute, doubly-refracting particles, in which are—(1) Minute plagioclase prisms; (2) iron ores (magnetite and pyrite ?), and (3) a large amount of viridite (chlorite ?). This rock evidently approaches in composition those diorites of the immediate neighbourhood in which the amphibole (here converted into viridite) preponderates over the anorthite or labradorite felspars. This dyke might be classed with diorite (aphanite).

Diorites.—Dykes of this class are of very frequent occurrence near the contacts, but are also found throughout the whole intrusive area, with the exception of the tracts of anorthite diorite and amphibole-gabbro, which they do not penetrate. These dykes are from a foot to 5 feet in width, and have not any common direction of strike. They vary much in texture, from finely crystalline or almost compact to a texture in which the crystalline individuals of white plagioclase and dark-green hornblende are clearly distinguishable by the naked eye. In extreme cases the individuals may be even ·25 inch in diameter. I have observed only one instance which could be described as a porphyritic diorite. This occurs traversing the gneissic quartz diorite near the contact at Swift's Creek.

I have prepared and examined slices of various of these dykes, which I now note.

Dense diorite.—Many dykes of this class occur throughout the district. An example taken from one penetrating the schists on the eastern side of the intrusive mass gave me the following:—The rock is micro-crystalline, having a crypto-crystalline ground mass in which are many minute plagioclase prisms, a little iron ore, and a large amount of viridite, to which the green colour of the rock is due.

Another dyke of this character which penetrates the amphibole granite near the eastern boundary, showed me, when examined as a thin slice, that it consisted of a crypto-crystalline ground mass, having traces of what may have been a glass basis. In this are many long and narrow prisms of plagioclase. A large amount of light-coloured viridite, in flakes and twisted fibres, is distributed throughout the whole mass. Quartz is rather plentiful in small clear grains, which, however, often suggest that they are secondary. Throughout these and throughout the whole mass are very many minute apatite needles. Ores of iron have been deposited besides those magnetite crystals, which may be regarded as original.

Crystalline Granular Diorites.—The dykes of this variety are found occasionally throughout the district, and are usually strong and persistent. One of them traverses the schists on the eastern boundary. As usual, the thin slice showed me that the rock has undergone much alteration. The main mass is made up of more or less imperfectly formed, but rather stout, prisms of triclinic felspars, all of which, with few exceptions, are completely altered into aggregates of some minute micaceous mineral. In none of those which still showed striations could I obtain measurements. Between these felspars there have been small, elongated prisms of hornblende, all now converted into strongly dichroic chlorite. Whatever little ground mass there was has become involved in the general micaceous and chloritic alterations. A little quartz fills in spaces.

Another and somewhat similar dyke traverses the edge of the metamorphic schists in the same neighbourhood. It runs for two or three miles, and varies in texture. I prepared samples taken from the most crystalline granular part of this dyke, showing the apparently least altered rock, and also examples from a little distance, where the alteration seems to me to be at a maximum. I found a thin slice of the former to be composed as follows:—(1.) Felspars numerous, and in well-defined prismatic crystals, both singly and doubly compounded. The angles of obscuration measured gave me from 15° to 23° 30′ on either side of the composition face, and this would, I think, point to labradorite. The felspars are all more or less converted into aggregates of some minute micaceous mineral (soda or lime mica ?). The inclusions are apatite and, rarely, small flakes of hornblende. (2.) Hornblende, in flakes or imperfectly formed crystals, showing the prismatic cleavage of 124° 30′. They are frequently twinned, and are strongly dichroic. They include portions of ground mass and magnetite. The hornblende has been in places converted into chlorite, with the production of iron ores. In another slice the hornblende was replaced by brown dichroic magnesia mica. Quartz fills in spaces between the other minerals. The sample taken from the most altered part of the dyke had a very hard, compact texture, and a reddish colour. I found it extremely difficult to prepare, in consequence of its great hardness and toughness. The slice showed me that it is a confused mass of flaky and fibrous aggregates. Some are radiating, some only divergent. Ores of iron have been extensively deposited between the flakes and fibres, most frequently amorphous, but also in octahedral crystals, and here and there in the mass are quartz grains. When it is possible to examine the fibres optically I found them to become obscured where the longer diameters are parallel with the plane of polarisation of one of the crossed nicols. The appearances seen in this rock resemble serpentinous alterations; but they are not pseudo-morphous. It appears to be a case of complete molecular re-arrangement of the rock with, perhaps, abstraction of some of the constituents. This dyke, in its original state, was evidently a crystalline granular hornblende and mica diorite.

Porphyritic diorite only occurs in one place, as I have before stated. A slice of the dyke showed me a crystalline granular ground mass, in which are many small, dark-coloured, not very dichroic flakes of hornblende. There are also minute aggregates, which I suspect to be felspar granules. Viridite is either disseminated, or occurs in patches, having a somewhat radial structure. In this ground mass are large dark-brown glassy porphyritic crystals of hornblende.

The slices of this hornblende are not very dichroic, are much fractured, and occasionally twinned. There is but little iron ore. The hornblende is very fresh and unaltered. It occurs in the form of I, ii, o. Besides these porphyritic hornblendes there are also porphyritic patches of alteration products, perhaps representing felspars, which are otherwise not present.

Amphibolites.—Dykes of this class occur principally at Riley's Creek, and bear much resemblance to the crystalline granular diorites, in which the amphibole preponderates to the almost exclusion of the triclinic felspars. A sample from such a dyke at the lower part of Riley's Creek, near the contact, is coarsely crystalline, and inclining to olive-green in colour. A thin slice showed me that the principal constituent is amphibole in not very perfect prisms, cross sections of which show the characteristic cleavage. It becomes translucent in shades of green or yellowish-green, and the sections are moderately dichroic. It is not fibrous, but yet not glassy, as are many of the hornblendes of the diorites. It takes up most of the space in the slice. Next to it in a mount is a colourless and not dichroic pyroxene, either separately or grouped, of several more or less perfectly prismatic crystals. The characteristic twinning of augite occurs. This being an augite-like pyroxene, with very little iron, is probably diopside. The angles of maximum obscuration of the amphibole and pyroxene I found to be as high as 16° 39′ in the former and 44° in the latter. The most interesting feature in this rock is, however, the constant intergrowth of amphibole and pyroxene. In Fig. 20 I give an example.

In another instance in the same slice the pyroxene formed the nucleus of the amphibole crystal. The alterations which I observe in this slice have been principally the production of an almost colourless chlorite, otherwise precisely similar in character to that I have described when speaking of the diorites as the result of alteration of the hornblende. It is rather broadly fibrous, undulating, and only faintly dichroic in shades of green. Iron ores have separated, and are deposited in the chlorite or in masses, either as magnetite or ferric oxide, and in the latter case it is in red and translucent flakes. I have also observed the incipient formation of chlorite as minute acicular fibres fringing the margins of the amphibole.

No felspars are recognisable; but if any existed they may be now represented by some small spaces filled by minutely-constituted, brightly-polarising aggregates. No quartz is met with in the slices.

In another sample obtained from a dyke in the neighbourhood of the last, I found the amphibole to be in prisms much drawn out in the direction of the chief axis, and prismatic cleavage well marked in the cross-sections. The angles of obscuration in these amphiboles are large, being, according to my measurements, as high as 21° 30′. Many of the smaller crystals are twinned according to the ordinary law. These crystals form at least two-thirds of the rock, the remainder consisting of alteration products, among which is the usual chlorite, and also the minute aggregates spoken of in the last. In this slice, however, there are also a number of long and narrow plagioclase prisms in all stages of alteration, and connecting the scarcely altered individuals with the resulting minute aggregates before spoken of. In the only instance in which I could obtain measurements of the angles of obscuration in the felspars I found them to be 5° on each side of the composition face.

A slice prepared from a third dyke in the same neighbourhood afforded me similar observations, with this exception, that in this case the colourless pyroxene amounted to perhaps one-third of the constituent minerals, and also constituted the nucleus of two crystals, thus showing that the simultaneous occurrence of amphibole and pyroxene is a case of envelopment and not of alteration.

Diabase.—The only dyke of this class which I have met with is found in the schists at a road cutting at lower Swift's Creek. A slice of this dyke I found to have a light-brown, cloudy, crypto-crystalline ground mass, in which are —(1.) Minute prisms of plagioclase, all of which are more or less converted into micaceous aggregates. (2.) Large porphyritic plagioclase prisms, in which the alteration is distinctly micaceous. Viridite has been deposited in these felspars. The micaceous alterations are mostly central, but also in some cases extend to the exterior. The angle of the principal optical sections in the sections of the crystals are from 15° to about 30°, thus pointing to labradorite. If this is so, the alterations must produce, as a colourless micaceous mineral resembling muscovite in its microscopic optical characters, a mica containing soda or lime. In other words, it suggests paragonite or margarite. Augite exists in yellowish crystals, which have, however, been mostly converted into chlorite. (4.) Magnetite, and also amorphous iron ores, probably the result of the alterations in the rock. (5.) Cavities filled by colourless carbonates, edged by delessite. This rock is evidently a porphyritic diabase, or, in accordance with the classification of Professor Rosenbusch, a diabase porphyrite.

(e.) The Contact Metamorphic Rocks.

Their Component Minerals.

Felspars.—In the contact schists, with the exception of one narrow zone of limited extent, the felspars are of extreme rarity. The triclinic soda and soda-lime felspars are in the minority, and the lime felspar anorthite is entirely absent.

I have found the soda and soda-lime felspars also as constituents of the aplite beds. These immediately adjoin the intrusive masses near Odell's Creek, going north and east round to near Sandy Gully Gap. Here, however, the plagioclase is of such extreme rarity that its presence but proves the general rule as to its absence. Where it occurs it is in well-formed, prismatic crystals, resembling those of the granites. I was not able to obtain any measurements. Felspars occur in the hornfels zone so rarely that it may be stated as the rule that they are not found there at all. The only instances I met with were in the actual contacts of the hornfels and quartz diorite. From the best example which I collected, which was taken from the adit of the Black Prince Mine, at Eureka, I was enabled to prepare a slice across the contact of the two rocks, the hornfels being in this case a very quartzose example. A number of granules and some perfectly-formed crystals of felspar are situated among the granules of quartz near the contact line. The position of these felspars, only when close to the dioritic rock, and their mostly sharp and well-marked outlines, proved that they are secondary, and not original, constituents of the sedimentary rock. The largest felspar crystal is composite as to one half and simple as to the other, the lower part of both halves being very homogeneous, except where crossed by a few laminæ. The angle of obscuration is not the same in the upper and the lower parts, being in the former 14° and in the latter only 11°. From the structure and optical characters, I think this felspar belongs to group 1 (albite or oligoclase). Besides the large crystal, there are other triclinic felspars in mere granules, in which no measurements could be obtained.

In the aplite bands which lie nearest to the intrusive masses there is, beside the small constituent amount of triclinic soda and soda lime felspars, which I have already mentioned, a very large amount of triclinic and a lesser amount of monoclinic potash felspars.

The triclinic potash felspar is crystalline granular, and nowhere well crystallised. It has shades of pale flesh red to white. In order to test the presumption raised by my first examination of some thin slices of these rocks, I broke up an average piece of the rock, and by aid of the lens selected a number of the minute flakes which had been separated from the most perfect cleavage. Some of these I examined qualitatively before the blowpipe, and others I prepared as microscopic objects; the former gave (BB) a slight sodium and a strong potassium flame reaction, and tested in the wet way gave a strong precipitate of chloride of platinum and potassium. Those fragments which I examined under the microscope by polarised light, and between crossed nicols, all showed more or less perfectly the peculiar twinned and cross-barred structure characteristic of microcline.

An examination of thin slices of this rock taken from near sketch section No. 1, sketch section No. 2, and sketch section No. 3, showed me that in each case the same peculairly twinned triclinic potash felspar formed the greater part of the crystalline granular mass. In Figs. 16, 17, 18, 19, I give some characteristic instances.

The orthoclase in this rock does not offer any marked peculiarities. It is quite subordinate, except locally.

In accordance with the plan upon which I have constructed this essay, there ought to follow here an enumeration and description of the other constituent minerals of these contact schists, On attempting this description, I have found, however, that it is better to sacrifice mere method to the greater convenience of describing the constituent minerals when speaking of the contact schists themselves, and to do this partly from slices of typical rocks, and partly from such slices in connection with the detailed descriptions of the sketch sections Nos. 1, 2, and 3, which will follow in the next few pages. All that is necessary, therefore, will be to mention now that the mica of the aplite beds is a colourless or slightly greenish silvery mica, having all the microscopic optical characters of muscovite. In typical aplite rocks it is extremely rare, but in other samples it increases so much in amount that the rock becomes a form of muscovite granite. In the latter case magnesia mica is frequently associated with it.

Quartz also occurs in the aplite rocks as an essential constituent. It occasionally contains fluid cavities with movable bubbles. Inclusions in the felspar or quartz of the aplite are extremely rare and undefinable.

It only remains before proceeding to speak of the contact schists, to refer to the small limited zone in which is found the felspathic rocks I have just mentioned.

The contact schists fall naturally into zones, of which the most highly altered immediately adjoins the igneous mass. In the immediate contact of the igneous and sedimentary rocks there are beds of a more or less well marked crystalline granular felspathic character; on one side they all join, and even are partly included in the igneous masses, and on the other alternate for a short distance with other contact sediments. They are composed mainly of crystalline grains of felspar and quartz, and have often, as an accessary constituent, a silvery or greenish muscovite mica. This last is locally so abundant that a muscovite granite results. The felspars are mostly triclinic. The quartz fills in interspaces as granules, but other spaces are filled by small crystalline grains of felspar. Such a rock resembles in some respects a granulite of the regional metamorphic series, but it differs in having a more granitic character, in having potash mica, and in wanting the constituents schorl or garnet which are characteristic of the granulites of the neighbouring regional schists. The most appropriate term for such rocks is *aplite*—a semi-granite. They may be regarded as being in the contact series the analogues of the granulites of the regional series of metamorphic schists.

Athough in hand specimens these rocks could scarcely be suspected to be altered sediments, yet the examination of them in the field left no doubt in my mind as to their original character, nor that their present condition is due to the complete molecular re-arrangement and metamorphism of the sediments.

I now come to speak of the next lying zone—hornfels. These rocks fall naturally into two groups, the quartzose and the quartz free, representing the sandstones and slates of their former condition. The paste which more or less cemented the quartz grains of the former probably resembled the main mass of the latter. The quartzless samples of hornfels which I examined I find to consist of a groundmass, and also of what may be called pseudo-nodules. The alterations are all micaceous. The groundmass consists of minute flakes of some colourless micaceous mineral which either forms aggregates of crumpled folia or else which are to a certain extent parallel, and then simulate a homogeneous crystal by becoming dark simultaneously when rotated between crossed nicols. The pseudo-nodules often approach the true nodules in character by having narrow margins of mica plates separating them in part from the remainder of the mass. I have usually found that there was a considerable amount of black amorphous substance in flakes in these spots, and this appears to be a form of carbon surrounding these pseudo-nodules. The ground mass consists of two kind of material; first, micaceous aggregates, or else small overlapping plates of mica, with larger plates interspersed in the mass. This mica is colourless, and reacts like muscovite. No hornfel that I have examined is without more or less magnesia mica as brown dichroic plates, which, however, are usually confined to the ground mass. I have not anywhere observed the interlacing thorn-like microliths which are so plentiful in the true nodular schists near at hand, excepting in one instance at the lower part of Sheep Station Creek, where I observed a few. Other microliths are probably minute mica plates, apatite needles, and colourless, imperfect crystals, whose nature I am unable to determine. In one example of hornfels taken from the immediate contact at that place where the amphibole granites have truncated the strata, I also observed very many minute black, dark green, or dark brown microliths, having brush-like terminations at one or both ends. These occurred generally in such manner that two or three crossed each other, thus forming a radiating group. On a very small scale, but much darker in colour, they bear much resemblance to bladed and also radiating amphibole (actinolite ?), which I have observed in a compact diorite near Bright. Perhaps these may be referred to the same class.* In another sample of schistose hornfels taken from near the same place, I observed spaces which were perfectly clear and colourless by ordinary light, but which, by polarised light, seemed at first sight to be mainly isotropic. On, however, using a higher magnifying power I found these spaces to break up into slightly discordant plates, which were certainly, although slightly, doubly refracting. The quartzose hornfel is composed, more or less, of irregular granules of quartz of the character of those of the normal sandstones. I observed no fragments of the felspars intermixed with them. The quartz granules composing this kind of hornfels are set in what was once a more or less plentiful paste, which, in the least-altered examples, resembles that which I have observed similarly placed in the Silurian quartzose sandstones of the district. The changes which have taken place in this paste are analogous to those I have

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* See as to these microliths Zirkel *Mikroskopische Beschaffenheit der Mineralien*, 1870, p. 491. In an example of nodular schist from Swift's Creek I have also found numbers of these acicular microliths; examined with a power of 350 linear, I found the larger ones to be yellowish brown in colour, and distinctly dichroic. The minute size, ·0015 x ·0003 inch, rendered it impossible to observe whether the plane of vibration coincided or not with the direction of the sides. The smaller individuals still appeared merely as black lines.

noted in the quartzless hornfels. The interspaces are occupied by aggregates of minute plates of some colourless mica, which reacts, like muscovite, where larger plates occur, and can thus be tested. Besides these there is always a considerable amount of brown dichroic magnesia mica interposed between and around the quartz granules; and the individual size of the magnesia mica is, as a rule, more considerable than that of the muscovite. The most remarkable alteration products are vast numbers of microscopic, round, oval, rectangular, and irregularly shaped plates, which cling to the surface of the quartz grains, and even seem often to be implanted therein. I have observed more than once where a swarm was situated apparently near the centre of the quartz grain, that I could cause a succession to appear by altering the focus of the object glass, without, excepting occasionally, being enabled thereby to detect any capillary flaw connecting them.

The alterations, therefore, which I observe in the contact schists are, outside of the aplite zone, wholly micaceous. In the conversion of the aluminous portions of the sediments into mica, the silica which would be set free seems partly to have been deposited surrounding the original quartz grains, and partly to have formed aggregates of crystalline grains in the less highly altered varieties. In the true hornfels, which may be regarded as one of the former quartzless sediments, the silica seems to pervade the whole mass, and probably helps to give the rock its peculiarly hard and, with the mica, its tough character. Whether the magnesia mica derives its magnesium from the sediments or from solutions, percolating the strata during their metamorphosis, I am not able, in the absence of comparative analyses, to conjecture, and must leave undetermined.

The hornfels group, besides consisting of quartzose and quartzless varieties, also includes compact and schistose members—the former close-grained, heavy, dark grey, nearly black or bluish black in colour; the latter having much resemblance to the structure of a fine-grained gneiss, with this exception, that the alternating folia are mainly quartz and mica. This latter variety is often extraordinarily contorted.

The changes which I have sketched become gradually less and less marked as the distance from the contact increases, until at from twenty to sixty chains the rock masses have only the character of those indurated sediments which I have already described.*

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* See *ante*, p. 20.

(3.) The Interrelations of the Rock Masses.

The Igneous Rocks.

In passing across the more or less well defined contact boundary between the sedimentary and igneous rocks of Swift's Creek to the area of the latter, I have usually remarked these to consist of rather coarse crystalline granular compounds of quartz, felspar, mica, and hornblende, in which a gneissic structure is always more or less marked. These peculiarities of structure extend for various distances, and their extent depends probably not only upon local differences of crystallisation and cooling, which may well be supposed not to have been everywhere the same, but also evidently in many places on the irregularity of the contact plane, in respect to which the present surface rocks would have been situated at greater or less distances. Those rocks first met with are varieties of plagioclase gneiss, or more properly gneissose quartz diorite. In proceeding still farther beyond the contact towards the central masses, an increasing change is found. The granitic rocks become darker in colour by the increased amount of magnesia mica; and, at the same time, they are harder and tougher. The gneissic structure passes into an irregular crystalline granular structure. The texture varies much from a fine-grained rock, composed mainly of minute scales of black mica and quartz, to a coarse compound of quartz, felspar and a little magnesia mica, or blackish green to black hornblende. Other varieties intermediate between these occur, either singly or else even irregularly massed in the rocks themselves. In proceeding southward the rocks become more dioritic in character, and parts are met with along the southern boundary of the intrusive masses where hornblende so preponderates as to produce rocks such as the amphibolites. These rocks extend along the contact from Eureka to Riley's Creek, and it is here that the peculiar amphibole-anthophyllite rocks are met with. Still further round the contact, and at the Sheep Station Creek Gap, are the anorthite diorites. The contact phenomena of these rocks and the sediments do not differ from those found where the intrusive rock is of a more granitic character.

Thus, the area of the Gum Forest and of the upper part of Swift's Creek is occupied almost exclusively by intrusive rocks of the classes quartz diorite, diorite, and amphibolite, in which the hornblende is often replaced by magnesia mica, when the quartz diorite in this their extreme form becomes, so far as physical character is concerned, true plagioclase granites. In leaving the Gum Forest and ascending toward the Tambo River, either by the Long Gully or the Sheep Station Creek,* a large tract is found to be entirely occupied by granitic rocks. We have here the usual physical character of country seen in granite areas—namely, rounded hills, but occasionally varied by summits crowned by rocks, or slopes dotted by weathered masses and tors of granite. The rock itself is usually a granitite or an amphibole granite, with varieties connecting both. Such granite rocks as these are found extending to the eastern contacts, where they are seen to have been intruded into the regional metamorphic schists and the less metamorphosed Silurian sediments of the district. The phenomena of contact in the granites are everywhere such as these I have described—namely, a strongly marked gneissic structure of the intrusive rocks near the contact, and perhaps an increase of potash felspar in them, due, I suspect, to the admixture of portions of the sediments which have been absorbed.

It soon becomes evident, in tracing out the contacts of the two groups of rocks at Swift's Creek, that the igneous masses are intrusive into and, therefore, younger than the sediments. The actual contact is, however, not always easy to point out, for the gneissose margin of the former and the greatly metamorphosed beds of the latter often interlock. But I have found, upon repeated examination, that those beds, such as aplite and hornfels, which alternate with the intrusive rocks, are, in fact, those extreme edges of the sediments which have remained attached to and in the consolidated igneous mass, while their extensions towards the sediments to which they belong have been denuded. I can also perceive that more than one irruption of igneous rocks has taken place, for I have observed that dykes nearly approaching the character of the amphibolites penetrate the granite and gneissic diorites. Similarly, I have observed that compact diorite dykes penetrate them, while the amphibolites, the amphibole-gabbros, and the anorthite diorites, so far

* The Sheep Station Creek falls into the Tambo River. The Sheep Station Gully is in the Gum Forest, and is the western branch of Riley's Creek. It is not lettered on the map.

as I know, contain no dykes. These dioritic and granitic rocks form a whole, as regards the sediments into which they have intruded, but in respect to each other, they are all also intrusive, and, I may say with some confidence, that the more hornblendic varieties are the latest in occurrence; so that we have the mental conception of a first invasion by quartz diorites and granites, followed by quartzless diorites, and these again by amphibolites, and bordered, except in the south, by a margin of quartzose plagioclase or orthoclase rocks whose gneissic structure is probably one of the phenomena due to contact with the sediments. Finally, we must also perceive that the metamorphism produced has been the result of all these intrusions, and, therefore, an intermittent process.

The Metamorphic Contact Rocks.

In describing the intrusive granites and diorites I passed from their contact with the sediments to them. I now reverse the process, and having briefly described the inter-relations of the intrusive masses, proceed to describe these altered sediments and their mutual relations, into which the former have intruded.

If we commence at the termination of the gneissic or granitic rocks into which the true quartz diorites appear to graduate near the contact, we shall find that the sedimentary rocks present to us certain appearances of alteration, which, broadly speaking, are applicable to the whole of the contacts surrounding the igneous masses. I may take an example from the lower part of Riley's Creek.

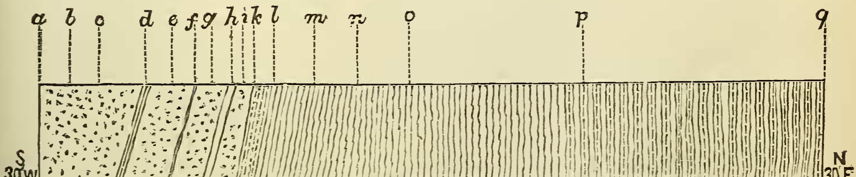

Diagram No. 1.—Section across Contact at Lower Riley's Creek.

Scale, about 40 chains to one inch.

a. Massive crystalline granular quartz diorites, with some magnesia mica.

b. Similar rocks, but with fine-grained portions, which are either in contorted foliations of short continuance, or in crystalline granular patches.

c. Similar to *b,* but the foliated portions more pronounced.

d. Massive, rather coarse, crystalline granular quartz diorites, as at *a.* In this is a band of indurated silicious hornfels. The beds are foliated, dipping south at 25°. They are traversed by irregular joints only a few inches apart, dipping north at 75° to 80°. The joints are silicified and very smooth. Silvery mica is deposited on some of the planes of foliation.

e. Massive quartz diorites, as at *a,* but having traces of a schistose structure.

f. Bands of hornfels, as at *d,* but only about 30 feet across in the whole.

g. Coarse grey quartz mica diorite, with a gneissic structure. This rock is composed of felspar (microcline, orthoclase, and a little plagioclase), magnesia mica, and quartz. The preponderance of triclinic felspars (including microcline) classes this as a diorite. Its structure is that of a gneiss.

h and *j.* There are here bands of schistose hornfels.

k. At this point the diorite-gneiss ceases, and there are thick bands of aplite. An example of the most felspathic variety showed me, when examined microscopically, that it is composed mainly of irregularly-shaped grains of felspar, the greater part of which is orthoclase, the remainder being microcline. Some grains are part monoclinic and part triclinic. There is no plagioclase and not much quartz filling spaces; nor is there any mica whatever.

l. The aplite gradually becomes less massive and more schistose, and alternates a little with schists.

m. Slaty or schistose sedimentary beds, the strike being east and west. These extend to *n.*

n. Finely-wrinkled micaceous schist, dipping south at 42°.

o. Bluish and greenish slates, only slightly micaceous.

p. Nodular argillaceous schist and micaceous quartz schist. This section crosses the strike of the beds.

I now give a second example from the Charlotte Spur, at a distance of about 120 chains westward from the last.

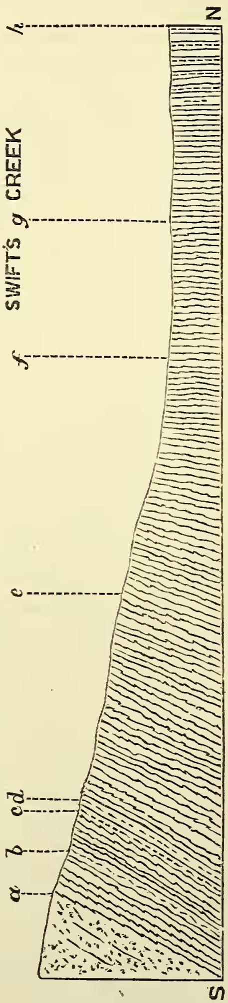

Diagram No. 2.—Section across Contact at Charlotte Spur, Swift's Creek.

Scale, about, horizontal 10 chains and vertical 700 feet to one inch.

The section is taken nearly north and south, and thus approximately lies at right angles with the strike of the beds.

a. The gneissic granite or diorite ends here, and a grey coloured, rather rough-textured schist commences, dipping south at 53°.

b. A band of granitic rock, much decomposed, conforming to the dip and strike of the schist, and about ten feet wide.

c. The grey schists end here. I prepared a thin slice from two samples which represented their average character from *a* to *c*.

The slices were prepared from schists, one of which was quartzose, and the other fine-grained and micaceous.

The former I found to be composed of grains and aggregates of grains of quartz, whose outlines are irregular. Between them are ragged-edged plates of brown and dull green mica. The paste cementing the quartz grains has been generally converted into an aggregate of minute scales of colourless mica, in which are far larger solitary plates, showing crystalline outlines, and also masses of slightly divergent plates of the same mica. I regard this as being muscovite. It is, however, the magnesia mica that reaches the largest dimensions, and it occasionally constitutes masses separating the quartz aggregates. There are only very faint traces of chlorite in some of the larger aggregates of muscovite mica. Black material occurs in ragged, opaque, and rather minute forms. It is not affected by hydrochloric acid, and is probably graphite. Other minute, black, or dark brown flakes are slightly translucent at their edges, and are therefore most likely a form of magnesia iron mica. The fine-grained sample showed me that which the general aspect of the schists in the field had suggested was the fact—namely, that they are mainly composed of mica, the quartz grains being few and small. In one sample, the quartz grains and the mica alternate with each other. The material which I have elsewhere spoken of as the "paste" has been wholly converted into mica, the ground mass being colourless, or pale green muscovite, with numerous flakes of brown magnesia mica scattered through it. There are scarcely any traces of chlorite. In this sample I observed the same opaque black substance in considerable amount, which I have spoken of as graphite.

d. Aplite in more or less irregular bands, conforming to the dip and strike of the schists. The character of this aplite is that already described in the last section. The total thickness of these bands is about 120 feet.

e. A schistose rock, similar to that described at *c.* A thin slice prepared from a sample taken from this place showed it to be a fine-grained foliated rock. The ground mass is composed of minute plates of mica, which is either colourless or faintly brown. In this mass are small grains of quartz and flakes of brown magnesia mica. The plates of colourless mica which form the ground mass of this rock are, as compared to those of *c*, much smaller in dimensions, and consequently, the mass being the same, more numerous. As before, there is a considerable amount of amorphous, opaque, black material, and minute black or dark brown flakes. Microliths are of minute size and undeterminable character; some, however, suggest minute specks of chlorite.

f. The schists at this point have in the distance from *e* (about eleven chains) changed their character. They are no longer micaceous, and are less schistose and more indurated. Samples collected from this place I prepared as thin slices taken parallel to and across the planes of deposit, so far as they were ascertainable from the crumpled and contorted condition of the rock. The former show by ordinary light a colourless ground mass which, in the thinnest edges of the slice, suggests overlapping, minute plates. In this are vast numbers of minute bent and contorted, pale greenish fibres, which, when lying perpendicular to the slice, are seen as dots. These fibres are often arranged parallel to each other, or surround the grains and lenticular masses of quartz which lie in the ground mass. The dimensions of these fibres are too minute to afford satisfactory observations as to their being or not being dichroic; but so far as I could ascertain, they are. These observations suggest chlorite. The slice prepared perpendicular to the bedding showed the rock arranged in simulated foliations, the alternations being a ground mass, such as I have just described, in which the chlorite fibres are very numerous, and arranged in a direction parallel to the bedding, and a ground mass in which the chlorite fibres are very rare. Between and in these alternations are grains and lenticular masses of quartz. Throughout the mass there are minute black particles which are not affected by hydrochloric acid.

g. Here the rocks have assumed the appearance of indurated sediments, alternating somewhat in texture, and dark bluish or greenish in colour. I prepared samples of both these rocks. A slice of the darker coloured rock (dull green) showed me that the ground mass is, as in *f*, colourless, and suggesting minute overlapping flakes. In this are vast numbers of minute chlorite fibres lying over each other in all directions. Traversing the mass are narrow and contorted veins of quartz; chlorite fibres extend from the ground mass into them, and their median line is marked by a chain-like row of such fibres linked, as it were, to each other. Besides these veins of quartz there are isolated grains and lenticular masses of grains of quartz. A slice of a somewhat more indurated and lighter-coloured sample from a bed adjoining the former showed a similar structure; but in this the chlorite is rather in flakes than in fibres, and is pale yellow or yellowish green in colour. In both varieties of rock there are occasional angular fragments of plagioclase round which the chlorite fibres have arranged themselves in a pseudo-flow structure.

As this point may be said to be the intermediate position between the contact and regional schists, the beds, in going northwards from this place across the strike, are increasingly altered. Nodules appear in one set of beds, while those alternating with them are indurated. The former are the nodular argillaceous schists, and the latter are the micaceous quartz schists before spoken of. At a distance of about ten chains from *g* these have completely assumed their distinctive characters as members of the regional metamorphic series of Omeo.

Following the contact beyond the last section, I obtained a third section across the contact, which I subjoin.

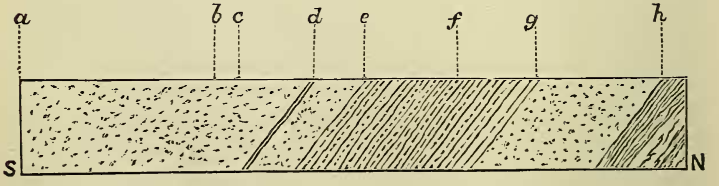

Diagram No. 3.—Section across Contact at Swift's Creek.

Scale, about 150 feet to one inch.

This is near the Old Fashion Reef, and about 55 chains to the south-east of section No. 2.

a. Grey felspathic quartz diorite.

b. Similar rock with more dark-coloured mica, and small, fine-grained, dark-coloured inclusions.

c. Similar rock with more mica.

d. The rock from *c* extends to here, where there is a band of aplite six inches wide dipping north-west at 60°.

e. Aplite beds, the bedding and jointing indistinct, but may be in accordance with that at *d*, and the jointing nearly perpendicular to that direction.

f. Some very irregular bands of schistose hornfels, say, six feet in width, traversed by many very minute joints.

g. Granitic diorite like that at *d*, but much decomposed.

h. Hornfels commence here. The rock is very hard and slightly spotted, but also in places schistose.

Beyond this, to the north across the strike, the schists gradually pass through the changes already noted.

In Odell's Creek still further round the contact towards Eureka, the contact of the igneous and sedimentary rocks is well displayed. The latter are much broken up, crumpled, and extensively altered. At some distance up the stream the sedimentary beds are seen to be cut across by the quartz diorites. The rocks resulting from these alterations and interferences are varieties of hornfels, from a close-grained, dark-coloured, crystalline rock almost resembling some varieties of basalt, to a schistose contorted rock resembling a fine-grained gneiss.

In places the contact is sharp, in other places the rocks interlock, and often the whole rock, igneous and sedimentary, assumes almost the same character. Many of the fine-grained inclusions in the granitic diorites along this contact strongly suggest that they are portions of sediments which have not been completely absorbed.

The instances which I have now given will sufficiently define and describe the group of contact schists, and are applicable *mutatis mutandis* to all parts of the contact surrounding the intrusive igneous masses. The diagrams show the series of contact schists to include indurated or silky slates, hornfels, and aplite, taking each of these to include varieties which connect the whole. They are clearly shown by their mode of occurrence, by the common direction of dip and strike, by the manner in which they alternate with and pass into each other, by varieties, and finally by the increase of crystalline alteration in approaching the intrusive masses, to have had a common origin and to have been all affected by the same influences. It cannot, I think, be doubted that these influences were connected with the intrusive masses, and entirely to be distinguished from those other influences which produced the regional metamorphism which has affected the Silurian formations up to the very boundaries of the contact schists.

The course which these contact alterations have followed is, I think, indicated by the microscopic examination noted in the description of diagram, section No. 2.

The least-altered rocks which still clearly retain their sedimentary character are seen to be highly charged with chlorite, and to have been somewhat altered in structure by the aggregation of crystalline quartz in lenticular masses and narrow veins.* In passing across the strata towards the contact it is found that the chlorite decreases *pari passu* with an increase of mica, and thereby with an increasing crystallinity of the rock until the immediate contact schists (as at the Charlotte Spur) are found to consist mainly of mica, with only faint traces of chlorite, or, as in other places where the contact rock is a typical hornfels, the chlorite has entirely vanished. These observations I observe to be in accord with statements made by Professor Rosenbusch as to the contact rocks of Bar Andlau in Alsace.† These observations may be thus shortly summarised :—

It is evident that there is surrounding the great intrusive masses a zone of altered sediments, but this zone is not a zone of sediments enfolding the mass after the manner of an envelope. The sediments are discordant in their bedding to

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* I cannot help suspecting that the colourless, doubly refracting plates, which in many cases are seen to form the ground masses of such slightly metamorphosed rocks as these, may be a mineral of the kaolin group in a crystalline form. This view has been strengthened by the observation that indurated, pale-coloured, upper Silurian mudstones in contact with an intrusive granitic mass at Kaffir's Hill, Foster, are seen under the microscope to be entirely composed of minute plates, which are probably orthorhombic. A qualitative examination of the rock showed it to be near kaolin in character.

† An inspection of the analyses of contact rocks from the normal Steiger schiefer to the granitite contact, given by Professor Rosenbusch (*Die Steiger Schiefer, &c., Strassburg*, 1877, p. 256), will show that "with increasing metamorphic intensity—with greater proximity to the granitite the percentage of water in the contact products decreases in a regular and visible manner."

the surface of the igneous rocks. Their directions of dip and strike are not only not in accord with the surface of the igneous rocks, but in the immediate contact the sediments are broken, crumpled, and cut off. These appearances of intrusion are most distinctly manifested when the contact crosses the direction of the strike of the sediments; while, on the other hand, the sedimentary beds when the direction of the contact and their strike coincide, are found to interlock in their most altered condition with the marginal rock masses of their intrusive neighbours. Such a contact may be imagined as I have roughly sketched it, and in its fea-

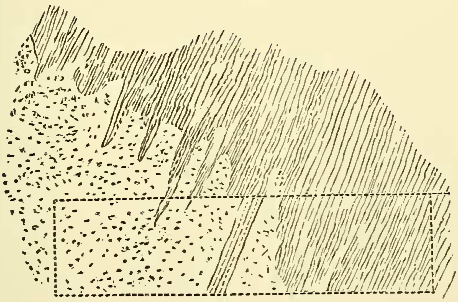

Diagram No. 4.—Representing the Contact.

tures it agrees with the observations which I have made as to similar contacts in other parts of Victoria. These appearances suggest most strongly to me, not only the intrusion of the plastic igneous rocks, but also as strongly the absorption, so long as the conditions remained the same, of portions of the invaded sediments; and further, that these processes must have been intermittent and of long duration. This contact zone is, as seen at the surface, of varying width. We should expect it to be so when we consider that the contact surface itself must be highly irregular, so that it must in places be far nearer to the present surface than elsewhere, or extend beneath it at varying angles with the horizon. From various approximate measurements, I believe the width of the zone from the main intrusive mass to those schists which are least altered, and wherein commences the regional metamorphism, to be from twenty to sixty chains.

The several zones may be defined as follows:—

1st zone (intimately connected with the intrusive rocks), aplite.

2nd zone, hornfels (compact and schistose).

3rd zone, indurated, wrinkled or silky slates, and sandstone.

Of these, the first is by far the narrowest, and is only of local occurrence. No hard and fast boundary can be drawn between the second and third zones, as they are connected by varieties.

THE QUARTZ REEFS OF SWIFT'S CREEK.

	Name of Reef.	Locality.	Strike or Underlay.	Width of Vein in inches.	Depth of Workings in feet.	Amount of Quartz Crushed.	Yield of Gold per ton.	Remarks.
						tons. cwt. qrs.	oz. dwt. grs.	
1	Snow Storm ...	Swift's Creek...	...	20	30	40 10 0	0 1 12 0 5 22·11	The crushings were of 15 and 25 tons.
2	Himalaya ...	Ditto ...	...	...	...	...	...	
3	Sebastopol ...	Ditto ...	U. South, @ 70°	7—8	40	40 0 0	0 5 0	
4	Charlotte ...	Ditto ...	St. North ...	6—8	10	30 0 0	1 10 0	
5	Elizabeth ...	Ditto ...	U. West, @ 70°	2—12	30	90 0 0	0 6 15	These adjoin on the same line. Four tons subsequently gave at the rate of 4 oz.
6	New Fashion ...	Ditto ...	U. West, @ 70°	2—12	60	160 0 0	2 0 0	
7	Midas	Ditto ...	U. South, 85° W. @ 65°	2	...	...	...	
8	Wilson	Ditto ...	...	...	...	...	...	
9	Old Fashion ...	Ditto ...	U. West, @ 54°	2—6	...	...	...	
10	Morning Star ...	Ditto ...	...	12	35	24 0 0	1 2 0 0 10 20	Two crushings of 12 tons.
11	Iron Duke ...	Ditto ...	U. West, @ 70°	4—10	60	...	...	The shoot of gold dipped to the north and was 150ft. along the reef; wedged out in length and depth. No returns made known.
12	Hand-in-Hand ...	Ditto ...	...	4—7	...	...	...	
13	All Nations' ...	Eureka ...	...	14	...	...	...	
14	Power's	Ditto ...	St. North ...	30	...	...	1 0 0	
15	St. David's ...	Ditto ...	St. North ...	...	25	66 3 0	0 8 13·77 0 10 9·60	Ran out and became poor.
16	Eureka	Ditto ...	U. South, 80° W. @ 86°	...	142	1128 0 0	...	The yield varied from 4dwt. to 1oz. 2dwt. per ton.
17	Black Prince ...	Ditto ...	...	6	53	122 0 0	1 7 0	
18	United Miners' ...	Ditto ...	St. North ...	...	...	...	...	No returns made known.
19	Harry Evans ...	Ditto ...	...	1—5	...	1 10 0	...	No returns made known.
20	Renovator ...	Ditto ...	...	18—20	60	151 0 0	1 0 0 0 5 4·28	Two crushings of 28 tons and 123 tons.
21	Rob Roy ...	Ditto ...	St. North ...	6	100	671 0 0	...	The yield varied from 1oz. 4dwt. 2·18gr. to 7dwt. 14·60gr. per ton.
22	Found at Last ...	Riley's Creek...	St. North ...	6—12	35	104 0 0	...	The yield varied from 1oz. 13dwt. 4·24gr. to 11dwt. 18·81gr. per ton.
23	Commin's ...	Ditto ...	U. West, @ 57°	6—12	26	106 3 0	...	The yield varied from 1oz. 8dwt. 11·13gr. to 12dwt. per ton.
24	Little Wonder ...	Ditto ...	St. North ...	...	...	9 12 0	1 10 17·5	
26	Caroline (Duke of Cornwall)	Lower Swift Ck.	...	...	...	580 0 0	...	The yield varied from 8dwt. to 12 dwt. 11·73gr. per ton.
27	Try Again ...	Riley's Creek...	U. West, @ 70°	6—24	40	12 0 0	0 11 5	Wedged out.

PART II.

4. The Alluvial Gold Deposits.

The alluvial gold workings have been carried on from the junction of Eureka Creek and Swift's Creek to the junction of the latter with the Tambo River: also in the Sheep Station Gully and in Riley's Creek, throughout almost the whole course of the latter. These deposits are now almost exhausted by the mining operations of the last twenty-five years. They were confined entirely to the stream bed, and more rarely to the points of the spurs. In tracing down Swift's Creek proper from Eureka and to near Tongeo West, I have found that the stream flows along the contact of the intrusive and the sedimentary rocks, and that it has cut down along this contact, whose plane dips at an angle of perhaps about 30° to 45° to the west. The streams which join Swift's Creek in this distance from the west flow only over sedimentary or metamorphic formation, and have not been found sufficiently auriferous to pay for working excepting in places near their junction with the main stream; and here the gold seems to have ceased in passing from the contact into the area of the altered slates and sandstones, as at Eureka. This points, therefore, to some connection between the contact of the intrusive and sedimentary formations and the source of the gold.

From Tongeo West to the Tambo River, Swift's Creek flows within the somewhat metamorphosed Silurian strata, and at an increasing distance from the intrusive granites, which are, however, most certainly situated at no great depth under foot. A connection between the gold and the intrusive rock masses is not so evident in this part of the district.

On leaving Swift's Creek and following up Riley's Creek it is found that gold has been extensively mined for in the stream for some distance above where the contact crosses it. A very rocky and precipitous part of the stream's course then ensues, in which little or no gold has been found. Near the junction of Sheep Station Gully with Riley's Creek the tableland known as the Gum Forest commences, and the fall of the stream being more moderate, gold has been retained. From here the auriferous deposits extend only a short distance up the Sheep Station Gully, but have been continuous along Riley's Creek up to the point where it crosses the southern contact of the diorites and the Silurian formation, at which place the creek ceased to be payable. Throughout its course Riley's Creek follows more or less along the line of contact of some highly-altered sediments and the diorites which have intruded into and metamorphosed them. Sheep Station Gully, on the other hand, flows almost entirely on the quartz diorites. Here, again, we have an indication of some connection between the source of the alluvial gold and the contacts of the igneous and sedimentary strata.

I need not enter into fuller particulars as to the occurrence of the alluvial gold, which would be of little interest.

5. The Auriferous Quartz Veins.

Quartz reefs have been more or less mined upon at Swift's Creek for many years, but are now, with one or two exceptions, abandoned. I give a tabulated statement of all the data which I have been able to collect as to the width of the quartz veins, the depth to which they have been worked, the amount of stone crushed, and the yield per ton. The statistics which can still be obtained are unfortunately very scanty. Those given have been compiled from the returns published by the Mining Department, and from *viva voce* statements made to me by persons who have been engaged in working the several mines.* An inspection of these tabulated data and an inspection of the map show :—

1. The gold-bearing reefs, with the exception of the Caroline (now Duke of Cornwall), are all situated on or in immediate proximity to the line of contact of the intrusive and sedimentary rocks.

2. That they are narrow, and have become unproductive, or have "wedged out" at or under 200 feet from the surface.

The gangue of these reefs is almost invariably quartz, but rarely, as at Eureka, it was—for instance, in the Renovator

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* In collecting these statistics I must express the great obligation I am under to Mr. W. Phipps, mining registrar at Omeo, and to Mr. Thomas Easton, J.P., of Omeo, who was formerly engaged in mining adventures at Swift's Creek.

mine—partly composed of carbonates of lime, iron, and magnesia, derived, no doubt, from the decomposition of the soda-lime felspars and hornblende of the diorites.

In order to ascertain what inferences may be drawn from the reefs themselves, I propose to consider a few of the mines as to which I have made notes.

Eureka Reef.

This quartz vein is situated on a spur falling towards Eureka Creek. It has been somewhat extensively worked by adits put in from a gully on the south side of the spur. The last mining operations were carried on at the west side, where an adit was partly driven in intensely hard quartz diorite, but was abandoned before reaching the reef. No. 1 adit, which I examined, follows the course of the reef, which winds much, varying in direction from N. to N. 25° W. Its average direction is probably N. 20° W. The underlay* in the adit is westward at about 80°. I found the reef to vary very considerably, both in underlay and in strike. In following the reef the adit was at first on the east side, but near the end crossed and followed the west side—that is, the "hanging wall." At about this place was, I believe, the "shoot of gold" in which the main shaft was sunk. To the north of this point the reef is very narrow, or even only indicated by the walls and an inch or two of "mullock." In places there are small bulges of quartz. The same features occur in passing up the higher stopes to the surface. The reef is entirely in a quartzose diorite, but there are traces of contact schists close at hand at the Black Prince Mine, and the main contact is at a distance of 20 chains west.

The footwall of the Eureka reef is a dull greenish or almost colourless compact rock of a somewhat felsitic character. A microscopic examination showed me that it is composed of aggregates of quartz granules similar to those seen in the quartz diorites, filling in spaces between altered minerals, having the shape of felspars. These latter are composed of minute scales and twisted flakes, and more rarely of plates of a micaceous mineral—perhaps muscovite if the crystals were originally orthoclase, or paragonite or margarite if they were soda or soda-lime felspars.

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* I here use the mining term "underlay" as indicating the angle formed by the vein with the horizon, and the term "dip" solely in reference to the angle of descent of the shoot of gold in the direction of the strike of the reef.

These pseudomorphs polarise as bright-coloured aggregates. In examining these aggregates in the thinnest parts of the slices I found them to be filled in those interstices which may have represented planes of cleavage by numerous black or dark green flocks, the nature of which I could not determine, but suspect to be chlorite. The quartz granules contain countless numbers of minute cavities. They mostly contain fluid, and some have minute bubbles. Some cavities are, however, evidentally empty. I observed also many undeterminable microliths. The rock is strongly impregnated by ordinary pyrites in modified forms of the cube. This rock has, I think, been subject to great alterations, of a character different to that of surface decomposition.

In the quartz which forms the gangue of this mine I found arsenical and ordinary pyrites, and galena, as also small amounts of zinc blende.

According to Mr. Easton, of Omeo, who was well acquainted with the mine when being worked, the "shoot of gold" was from 30 to 40 feet along the course of the reef and dipped north at 66°—70°. It yielded from one to two ounces per ton of stone. He informs me also that the shoot was followed downwards to a depth of 130 feet when the workings were discontinued. The high yield quoted by this gentleman seems at the first glance to be inconsistent with the tabulated statements; but an examination of the mine showed me that much poor stone had been taken out far beyond the shoot of gold, and, in fact, a great amount of work done and money expended uselessly.

Rob Roy Reef.—This is situated at no great distance from the Eureka and Black Prince Mines, and immediately upon the contact line. The reef crops out along an extremely steep spur between the Sheep Station Gully and Eureka Creek. Adits have been driven at various times into the hill along its outcrop. The workings which were in operation when I visited the mine last were carried on by two adits. In the upper one the average thickness of the quartz vein was 6 inches. Generally speaking the reef has quartz diorite on one side and highly altered contact rock on the other, and underlies west at about 78°. To the southward where the reef leaves the contact and is wholly in the quartz diorite, it narrows to 2 inches, becomes poor, and then dies away.

The main workings at the time of my visit were in the lower adit about 100 feet below the surface, the width of the reef then being as much as 15 inches, and it yielded about one ounce per ton. It underlies in this adit west at from 70° to 80°. The gold occurs in a vertical shoot of some 20 feet along the course of the reef. At the north end of the shoot the reef narrows very much, and in one place is quite wanting, there being then nothing remaining but the two walls almost in contact. To the southward of the shoot, so far as the workings extend, the reef does not wedge out, but becomes poor.

The following sketch will illustrate the position of the reef on the lower workings and in the centre of the shoot.*

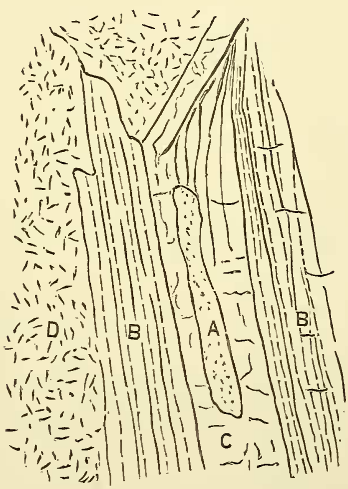

Diagram No. 5.—Sketch of the Quartz Vein at the Rob Roy Mine.

a. Horse of silicious felsitic rock, containing much ordinary and arsenical pyrites.

b. Finely crystalline foliated contact rock, with a little pyrites. In places it is very micaceous.

c. White translucent vein quartz, about 8 inches in width, with arsenical pyrites (yields about 1 ounce per ton).

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* Mr. Forsyth, the owner of this mine, who has had great practical experience in the Swift's Creek reefs, said to me in speaking of them—"The reefs here, as a rule, always wedge out not far from the surface, and when they wedge out the walls are very hard." The bearing of these statements will, I think, be seen further on.

d. Quartz diorite.

Elizabeth Reef.—This reef is situated on the steep hill forming the south side of the valley of Swift's Creek, near the Charlotte Spur, and is near the present line of contact. It is in gneissic and granitic rocks, which, as I have pointed out, form the margin of the intrusive mass in many places. An examination of the neighbourhood showed me that although the actual contact is in the stream bed, and at some distance lower than and to the north of this mine, its plane originally extended along the hillside to the summit of the ridge, where traces of contact rock still exist as outliers, forming isolated nobs in the granitic ridge. The line of reef extending north and south from near the summit to the stream indicates that it fills a fissure penetrating through the contact rocks into the underlying intrusive masses.

When I examined the reef it was being worked. I found the shaft situated about 40 chains up the hillside from Swift's Creek. The reef near the surface had an underlay to south 85° west at 60°. It was 9 inches in width, with granitic walls. On descending the shaft between 30 and 40 feet, I found the appearances indicated in the subjoined sketch.

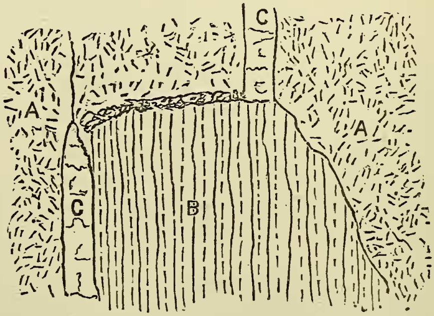

Diagram No. 6.—Sketch of the Quartz Vein at the Elizabeth Mine.

a. Coarse gneissic quartz diorite, very much decomposed.
b. Schistose hornfels.
c. Auriferous quartz vein.

The reef was here only 4 inches in width, and had a slight underlay to the east.

These examples may serve to illustrate the reefs of this district, with the exception of one at Lower Swift's Creek, formerly known as the Caroline, and now as the Duke of Cornwall. This reef is at a distance from the contact, in the nodular argillaceous schists and quartz schists which fringe the area of regional metamorphism.

I note the following as to this reef:—This quartz vein runs east and west, and thus forms an exception to the general rule at Swift's Creek. It crosses a spur from the range on the north side of the stream, and adits have been driven from both sides. Most work has, however, been done at the eastern end of the lode.

There are two parallel veins distant a few yards apart The veins vary in width. The quartz is somewhat glassy and crystalline. Pyrites is less frequent here than is the case in many other reefs of the district, and the gold is rather generally diffused in small particles than found in any defined "shoot." At the western end of the lode No. 1 adit was driven for 150 feet in the northern vein, the width of the quartz being about 22 inches, and having an underlay of about 80° north. Stone from this adit crushed from 6—8 dwt. per ton. The cap only of the southern vein at the western end was opened up, but a shaft was then sunk to 50 feet, the quartz being about 40 inches wide, and 15 tons of stone taken from this place gave at the rate of 8 dwts. 8 grs. per ton.

At the eastern end an adit has been driven for some 200 feet along the course of the lode, and the vein stoped out to the surface.

Returns given in the quarterly reports of Mining Surveyors and Registrars, published by the Department of Mines, show that the stone from these adits yielded at the rate of 11 dwts. per ton.

The mine is now idle. This vein has as yet never been thoroughly tested. It may probably extend to greater depths than any other of the reefs opened at Swift's Creek.

The quartz reefs of Swift's Creek may be classed as (1) those situated in the line of contact between the intrusive masses and the sediments, and (2) those situated in the regionally metamorphosed Silurian beyond the contact. I have shown that the former penetrate through the contact into the underlying quartz diorites; that they have been found to be richest near the surface, to dwindle away as they penetrate deeper, and to become less auriferous, or cease at no great depth from the surface. It may, perhaps, be of some significance that, when the reefs discontinue, the dioritic rocks, as a rule, cease to be decomposed. Some few auriferous reefs have been discovered, and worked within the diorite area; but in these cases isolated patches of contact schists associated with them prove that the general absence of these rocks is in reality only due to denudation. The occurrence of these quartz veins in the decomposed diorites adjoining sediments is paralleled by the occurrence of auriferous quartz veins in decomposed or mineralised dykes elsewhere.

At Swift's Creek the auriferous and metalliferous quartz veins are evidently connected with a vast mass of intrusive and often granitic diorite. In other parts of Gippsland auriferous quartz veins are found in connection with dykes of similar mineral character. I take as instance the dyke and reef at Kaffir's Hill, Stockyard Creek, and the dyke and reef at Walhalla.

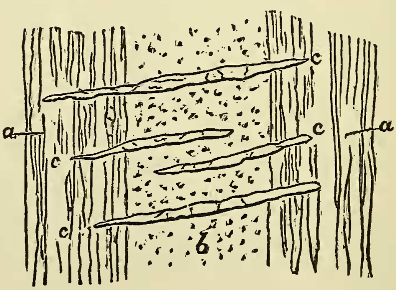

Diagram No. 7.—Dyke and Reef at Stockyard Creek.

(*a.*) Silurian (upper ?) mudstones.
(*b.*) Granitic dyke.
(*c.*) Auriferous quartz veins.

In this instance the auriferous quartz veins pass through the dyke, and penetrate the sediments on each side. The dyke, which is from a few feet to 200 feet in width, is almost completely decomposed; indeed, so much so as to rapidly crumble away when brought to the surface. The outline of porphyritic felspar crystals in a kaolinised state can be recognised in the more granular portion. No hornblende or mica is visible in this rock, nor could I determine whether any secondary mineral products existed which could be referred to the alteration of these species. The compact portions of rock which were brought up from the mine, and came from the contact, seemed to me to be indurated mudstones; these, under the microscope, in thin slices, proved to consist of aggregates of minute scales, suggestive of an orthorhombic mineral. A qualitative examination pointed to kaolin. This dyke has not yet been worked to such a depth as to have reached the less altered stone. The gold is found in the quartz veins, extending into the slate country, which is also, together with the quartz, much impregnated by iron pyrites.

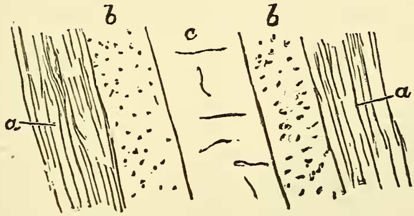

Diagram No. 8.—Dyke and Reef at Walhalla.

a. Silurian slates (upper ?).
b. Dyke.
c. Auriferous quartz veins.

In this reef, part of which is being mined by the well-known Walhalla and Long Tunnel Companies, the auriferous quartz lies, as a rule, more in the contact of the dyke and of the silurian slates than is the case in the instance just given. The dyke is a compact or fine-grained diorite of an almost felsitic character,* which is highly mineralised by arsenical and iron pyrites; but, as a rule, is rather indurated and mineralised than decomposed. Some slices prepared from samples of this rock—for which I have to thank Mr. Rosales, F.G.S., of Walhalla—showed me :—

1. Cryptocrystalline ground mass, in which crystalline grains of quartz were discernible.

*Professor Ulrich calls this a "diorite-aphanite." See *Descriptive Catalogue of the Specimens in the Industrial and Technological Museum, Melbourne*," 1875.

2. Spaces filled by alteration products, forming crystalline aggregates, in which quartz predominated. The smaller spaces had the form and presented traces of hornblende.

3. Crystals of arsenical and ordinary pyrites, surrounded often by crystalline quartz. This example shows distinct marks of alteration, and the Fe and As pyrites are evidently secondary to the injection of the dyke stone.

These instances illustrate the auriferous quartz veins connected with dykes. They might be much extended by references to Wood's Point and elsewhere; but these given will serve to show their mode of occurrence, and for comparison with the reefs of Swift's Creek. For comparison with the diagrams just given, I now subjoin one illustrating the manner in which I conceive the Swift's Creek reefs to occur.

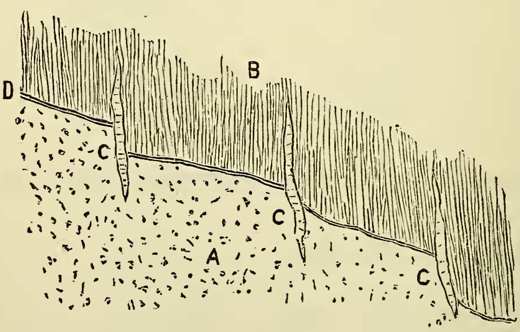

Diagram No. 9.—Contact at Swift's Creek with Quartz Veins.

(*a.*) The intrusive diorite mass.
(*b.*) The Silurian sediments (contact schists).
(*c.*) Auriferous quartz veins.
(*d.*) The plane of contact.

The plane of contact would give passage to heated waters or vapour accompanying the eruption of the diorites. It would probably resemble contacts between the subterranean masses of modern volcanoes and the adjoining sediments. It is in such contacts, and the fissures connected with them, that we may conceive metalliferous deposits to take place. In the case of Swift's Creek all the reefs, with one exception, that have been mined upon comply with the requirements of such an hypothesis. The exception, as I have before said, is the Caroline Reef, which penetrates the nodular argillaceous schists at a distance from the granitic contact. Such fissures as those indicated would tend to pass upwards through the schists, but would not, I conceive, be found to penetrate downwards into the consolidated igneous mass.

Denudation and erosion acting along the contact would suffice by the wearing down of successive small auriferous veins to supply the large amount of alluvial gold which has been found at Swift's Creek.

In all the cases now given, including those at Swift's Creek, the bounding rocks, as well as the reefs themselves, are more or less highly impregnated by pyrites, which are often richly auriferous.* At Swift's Creek, in addition, there is locally some amount of sulphides of lead, copper, and zinc.

In the upper parts of the veins percolating surface waters and atmospheric influences have decomposed the sulphides, while below the water-level these usually remain unaltered. It has further, according to my experience, been frequently found that the amount of gold has been relatively larger in the vein above the water-level than below it. Two explanations might, I think, be given of the presence of the metallic sulphides and of the gold—(1) That the ores and gold had been collected in solution from the superior or from the bounding rocks; (2) that they had been transported in solution from below upwards. I think that a third alternative—namely, the injection of the ores and gold with the molten substance of the dyke—need not be considered. In either of the two former alternatives the vehicle must, I think, be held to have been water or water vapour.

If we were to assume that the gold and metallic ores have, together with the quartz, been deposited in these fissures from percolating surface waters which have abstracted them from the superior or bounding rocks, we must then further assume that this process is constantly operative to keep pace with unceasing denudition of the surface, and that a concentration of gold has taken place above the water level. If, on the other hand, we were to assume that the deposition of ores and gold took place with the quartz in these fissures

* Tailings taken from Mr. Forsyth's mill at Swift's Creek gave, according to an assay by Mr. J. C. Newbery, at the rate of over 70 ozs. of gold per ton.

from waters not necessarily and immediately proceeding from the surface, but connected either as water or water vapour with the injection of the dykes or the intrusion of the masses, then those deposits below the water-level would be derived from below and from sources which cannot be at present pointed out, owing to want of data.* The metalliferous deposits below the water-level would then be contemporaneous with the formation of the dyke, while above the water-level the ores would have undergone changes due to the ceaseless reactions set up by meteoric waters, and a concentration of gold might take place. In fact, such changes as are indicated as being in progress at the Alison Mine, Costerfield, "where the highly saline water makes its way through the roof of a drive, and then deposits a mammillary crust of a brown colour, which, upon analysis, was found to contain hydrated oxide of iron, oxide of antimony, sulphide of antimony, gold and silica, with some alkaline sulphates and chlorides. As the block of ground is completely severed by workings in the course of the lode, the water must come from above, the strata on either side being dry."†

The second hypothesis is, I think, most in accordance with the facts observed as to the reefs in connection with dykes or intrusive masses.

At first sight these explanations would seem to be scarcely applicable to quartz veins of the second class—namely, such as are found in the silurian sediments unconnected with

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* A discussion of this question more fully would lead me into the consideration of regional metamorphism, which would be beyond the scope of this essay; but I may now point out that where sediments are invaded by igneous masses, before they have been re-elevated after their formation above the sea-level, the saline waters included in them during their deposition would supply not only a vast amount of heated water and water vapour, but also materials for the regeneration of the sediments as mica schist, gneiss, and granite. It may be broadly stated that the mineral constituents of sea-water are the complement of the sediments. The experiments of Dr. T. Sterry Hunt on the porosity of rocks proves how large an amount of saline water may be included in uncrystallised sediments, and thus become available, as I have suggested, for the regeneration of the sediments as metamorphic rocks, and to provide the alkali for the soda and soda-lime felspars. These triclinic felspars are a marked feature in the regional metamorphic schists of Omeo. Professor Rosenbusch has shown that in the contact schists of Bar Andlau the amount of water sensibly decreases as they become more crystalline in nearing the contact. (*Hunt's Chemical and Geological Essays*, p. 164. Rosenbusch's *Die Steiger Schiefer*, p. 256).

† J. Cosmo Newbery, B. Sc., Analyst to the Department of Mines. *Report of Progress of the Geological Survey of Victoria*, Par IV. p. 175.

dykes.* But they will be more applicable if we regard the fissures in such cases as penetrating the strata to varying, but as yet not ascertained, depths at which the igneous (granitic) masses underlie all Victoria.

On these views it would be reasonable to conclude that such contacts and fissures would, during periods of great igneous (volcanic) activity, give passage to heated waters and water vapours permeating the strata, and which, in passing through heated rocks, could carry minerals in solution and ultimately deposit them. "In these deposits we could recognise the mode in which the various metals were brought up from deep down in the earth's crust, and deposited in holes and crannies which are accessible to man as mineral veins."† If these views are well founded, and if, as seems to me, regional metamorphism and vulcanicity are intimately connected, we should expect that during all periods of volcanic activity or of metamorphism mineral veins should be formed.

In that part of the geological record which remains to us in Victoria, as exhibited in North Gippsland, we have evidence of volcanic action on a grand scale at the close of the Lower palœozoic ages, and in a less scale throughout the succeeding record until its abrupt termination at the close of the Devonian period. In Tertiary and in more recent times volcanic activity has left the plainest records for our study. Thus, if the views I have stated can be supported, we should expect to find a succession of mineral and auriferous veins commencing with the earliest regional metamorphism of the Silurian strata and extending onwards. Such a succession of veins I suspect there is, for they are found penetrating Silurian strata which are overlaid unconformably by Devonian sediments, and not passing upward into the latter. The discovery of an auriferous quartz vein at Freestone Creek in strata which are most probably of Middle Devonian age, and the occurrence of alluvial gold in situations which suggest that it has been derived from the Upper Devonian Iguana Creek beds, supports this belief. But the greatest number of auriferous veins seem to me to have been formed at the close of the Upper palœozoic age. In other

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* As at the Crooked River—*e.g.*, the Good Hope Mine.

† Professor Boyd Dawkins, as reported in *Chambers' Journal*, 31st May, 1877, at the Manchester Geological Society, May, 1877, when describing his visit to Vesuvius.

words, the production of auriferous quartz veins seems to have been in proportion to the igneous (volcanic) activity of the period.

General Conclusions.

I have endeavoured to state so fully the evidence in regard to the Swift's Creek district in its various geological, petrological, and mineralogical aspects that it is scarcely necessary to do more than to finally state the conclusions to which the careful consideration of this evidence had led me; and these conclusions are as follow:—

1. The intrusion of the Swift's Creek granites and diorites took place after the close of the Silurian and before the commencement of the Upper Devonian periods, and was probably connected with the volcanic activity of that time.

2. The Swift's Creek granites and diorites were intruded into the Silurian formations after the regional metamorphosis of the same, and the intrusion took place where the metamorphic change ceased.

3. The granites and quartz diorites were the earliest in time, and were followed by the more basic diorites and amphibole-gabbros.

4. The intrusive igneous rocks disturbed the sediments along the contacts, and partly absorbed them. They also effected a metamorphic change in them analogous to that effected by regional metamorphism. The contact metamorphism is most intense in the sediments immediately in contact with the igneous masses, and decreases in intensity outwards.

5. The metalliferous veins were probably produced at the time of the granitic and dioritic intrusions, and the lodes were formed in the contacts or in fissures connected therewith.

6. Denudation and erosion, which have laid bare the igneous masses, also set free the gold from the veins occurring in the contact, and thus supplied the alluvial gold deposits.

Note—Since writing this paper I observe that Mr. Daintree has arrived at somewhat similar conclusions as to the genesis of the auriferous reefs of Queensland. See Note on Certain Modes of Occurrence of Gold in Australia, by Richard Daintree, Esq., F.G.S., *Quarterly Journal of the Geological Society*, vol. xxxiv., p. 431.